SCIENCE ABSTRACTS.

Section A.—PHYSICS.

JANUARY 1917.

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SCIENCE ABSTRACTS.

Section A.—PHYSICS.

JANUARY 1917.

GENERAL PHYSICS.

1. *Integrating Device.* **M. D. Hersey.** (Washington Acad. Sci., J. 6. pp. 617–620, Nov. 4, 1916.)—An approximate method is given for evaluating the integral $I = \int_{x_1}^{x_2} f(y)dx$, in which $f(y)$ is stated analytically, but in which the relation between y and x is available in the form of a curve only. When $f(y)$ takes the form y, $y^2/2$ or $y^3/3$, the integral becomes respectively the area, the statical moment, or the moment of inertia, about the x-axis, of the plane figure bounded by the curve, the x-axis, and the limiting ordinates at x_1 and x_2. These problems are frequently solved by plotting an auxiliary curve of squares or cubes, and then determining an area by any convenient method. The method here described gives at least equal accuracy, and, moreover, the applicability of the device is not limited to these particular functions. The device consists of a templet, cut out of stiff paper, celluloid or sheet metal. In its simplest form the templet is bounded by two perpendicular lines and a curve, called respectively the back, the base, and the front of the templet. It is arranged so that its base can slide along the x-axis. Starting with the back at x_1, make a mark where the front of the templet crosses the (x,y) curve. Then slide it along until the back comes to the mark, and make a second mark where the front now crosses the curve, and so on. Let n be the number of steps necessary to travel across from x_1 to x_2 in this manner. An approximate numerical value of the integral will then be $I = nC$, in which C is a known constant for a given templet. In order to obtain this simple result it is only necessary that the front of the templet be cut to the curve $f(Y) . X = C$, where X and Y are the coordinates of any point on the templet curve relative to the back and base as axes. If two such templets are used back to back the accuracy of the result is enhanced; the appropriate formula is then $I = nK$, where $K = 2C$. Any number may be chosen for K, but it is desirable that K be a multiple of 10, provided this does not make the device too large or too small. A function met with in barometic altitude calculations is the integral of the reciprocal of the ordinate of an empircal curve, $\int_{x_1}^{x_2} (1/y)dx$. The templet needed for stepping off this integral is simply an inverted triangle. To integrate any function $F(x)$ which can be written

$f[\phi(x)]$, it is only necessary to evaluate $\int f(y)dx$ along an auxiliary curve $y=\phi(x)$. The result will be $\int F(x)dx$. Suppose, for example, $F(x)=\epsilon^{-x^2}$, then $\phi(x)=x^2$ and $f(y)=\epsilon^{-y}$. Cut out a double-faced templet to the curve $\epsilon^{-Y}.X=$ const., that is, to the curve $Y=\log 2/K+\log X$, in which K is chosen at pleasure. If n is the number of steps needed for traversing the curve $y=x^2$ from x_1 to x_2 with this templet, then $\int_{x_1}^{x_2}\epsilon^{-x^2}dx=nK$. The device therefore is not limited to problems involving empirical curves to start with. It is applicable also to cases in which the integrand is given analytically. It will be practically useful in such cases whenever $F(x)$ is sufficiently complicated to warrant the trouble of dealing separately with the two functions $\phi(x)$ and $f(y)$. A. W.

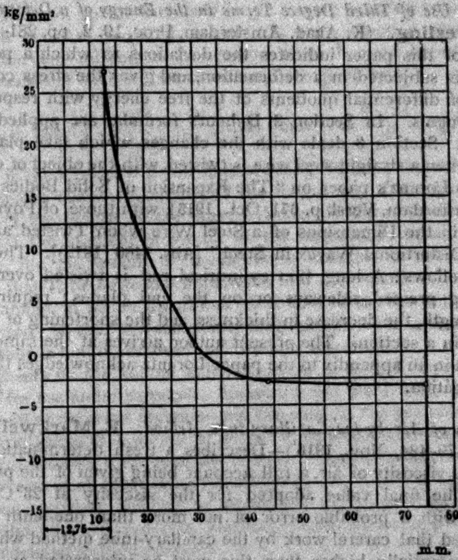
2. *Rapid Density Determinations.* **C. Chéneveau.** (Journ. de Physique, 6. pp. 108–110, March–April, 1916.)—Describes a simple balance form of hydrometer in which a glass sinker, immersed in a tube of the liquid to be studied, is balanced by a weight system in such a manner that the position of the weighted arm gives at once, by means of a pointer moving over a scale, the density of the liquid. In this way densities can be rapidly determined by unskilled observers to an accuracy of 0·1 % or less. J. W. T. W.

3. *Relation connecting the Derivatives of Physical Quantities.* **M. D. Hersey.** (Washington Acad. Sci., J. 6. pp. 620–629, Nov. 4, 1916.)—Given the fact that some relation of unknown form $Q_0=f(Q_1, Q_2,\ldots Q_{N-1})$ subsists between N physical quantities $Q_0, Q_1, Q_2\ldots Q_{N-1}$, no others being involved, it is required to deduce a relation of known form $\partial Q_0/\partial Q_1=F(\partial Q_0/\partial Q_2, Q_0, Q_1, Q_2\ldots Q_{N-1})$ such that at any point whose generalised coordinates Q_0, Q_1, Q_2, etc., are given, the value of any one of the N—1 partial derivatives of Q_0 can be computed from any other. Thus it is required to calculate one of the component slopes of a generalised surface from a knowledge of another, although the equation of the surface is not available. The interest to the physicist of this problem lies in the fact that he may wish to learn the value of a derivative not readily accessible to experiment, in a case where some other derivative of the same quantity can easily be observed. It is here shown that a definite solution can always be obtained, provided certain dimensionless products of the N quantities are held constant. The result depends upon and is a corollary to Buckingham's Π-theorem, according to which any complete physical equation is reducible to the form, funct. $(\Pi_1. \Pi_2,\ldots\Pi_i=0)$ in which the Π's are all the independent dimensionless products which can be built up by combining in any way the N physical quantities involved. The theory given is illustrated by considering (1) a journal bearing, for which it is required to calculate the effect of altering the size of the machine from a test in which nothing is varied but the rate of pumping oil through the bearing; (2) a rolling-ball viscosimeter, for which it is required to find the effect of gravity in terms of the effect produced by changing the size of the instrument. A. W.

4. *Strains caused by Heat in the Tube of a Gun.* **M. Ôkôchi.** (Math. Phys. Soc., Tōkyō, Proc. 8. pp. 520–538, Sept., 1916.)—Three experimental "guns" were constructed, of gun material, having an inner diam. of 25 mm., outer diam. 149·5 mm., and length 70 mm. The first was a single cylinder, the second had an outer tube shrunk on to the inner, and the third consisted of three such cylinders. The whole gun is electrically heated to about 185° C.,

then either the inner or the outer surface is water-cooled, and temperature measurements are at once begun and taken every 10 secs. Four thermo-elements of silver-constantan are employed, placed radially at different distances from the axis. Numerous tables with corresponding curves are given. It is found that the empirical equation connecting temperature (θ) with distance from axis (r) is $\theta = a + bc^{r}$, where a, b, and c are constants. The tensions in the gun tube are then deduced from formulæ involving the several elastic constants of the material. An example is given below in the case of the treble cylinder, the temperatures having been taken 140 secs. after the inner surface had been water-cooled.

Radius in mm.	12·75	20·0	30·0	43·75	60·0	74·75
Temp., °C.	24·0	56·38	80·17	94·0	99·44	101·0
Tangential stress (kg./mm.²)...	27·15	13·29	0·95	—2·79	—3·39	—3·20



If shooting proceeded at once after cooling the inner surface, the material would be in danger of cracking, owing to the heat strain acting at the same time as that due to the powder gases. If, however, the exterior surface is cooled the two strains might to some extent counteract each other. It might happen that, with very cold weather, after a few shots the tube would burst owing to the strain set up by the unfavourable temperature gradient. The influence of the compound tubing on the conductivity seems to be of small importance, but in the case of bad workmanship, involving a space between the tubes, this would increase the strain due to uneven temperature. T. B.

5. *Elastic Properties of Phosphor-Bronze Wires.* **A. J. Oehler.** (Phys. Rev. 8. pp. 465–469, Nov., 1916.)—Describes an investigation of the variation with amplitude of the period of vibration in phosphor-bronze wires. It is

found that there are three distinct classes into which the wires can be divided. In the first of these the period of vibration decreases with the fall in amplitude. In the second class the behaviour is similar to Class I in the larger amplitudes, but makes a departure from that type at an amplitude of about 4 degrees per cm. length of the wire, and from that time on the period increases as amplitude decreases. Class III shows the greatest departure from a constant period, and indicates a continuous increase in period as the amplitude decreases. It is found that, as a rule, drawing the wires has a tendency to increase the effect of a varying period with the amplitude; that in general, long-continued vibrating results in a wire's falling into Class II, while long-continued annealing results in a wire's falling into Class III. It is concluded that phosphor-bronze wires are not desirable as delicate suspensions in many cases where they are used at present. J. W. T. W.

6. *On the Use of Third Degree Terms in the Energy of a Deformed Elastic Body.* **J. Tresling.** (K. Akad. Amsterdam, Proc. 19. 2. pp. 281–286, 1916.)—Section I of this paper indicates the deviations to which a point of an elastic body is subjected in a deformation, and gives the stress components as the sum of differential quotients of the free energy with respect to the strain components. In Section 2 Duhem's formulæ are applied to some special cases. Section 3 deals with the changes which take place in the dimensions when a straight steel wire is twisted, with the object of comparing the results in Lorenz's paper on "The Expansion of Solid Bodies by Heat" [K. Akad. Amsterdam, Versl. p. 671, Oct., 1915], with those of Poynting "On the Changes in the Dimensions of a Steel Wire when Twisted and on the Pressure of Distortional Waves in Steel" [Abs. 1480 (1912)]. The problem raised is as follows: A long, thin cylindrical rod is twisted over an angle without being pressed sideways or on the end planes; required is the increase in length, the decrease in thickness, and the shortening of the radius at any point in a section. The present author arrives at the same result as Poynting, and in an appendix to the paper Lorentz acknowledges the validity of the investigation. H. H. Ho.

7. *Viscosity of Air by the Capillary-tube Method.* **E. Markwell.** (Phys. Rev. 8. pp. 479–484, Nov., 1916.)—Describes a fresh determination by this method of the viscosity of air, a full account being given of the precautions observed. The final value adopted for the viscosity at 23° C. is $\eta_{23} = 1{\cdot}824 \times 10^{-4}$ with a probable error of not more than one-tenth per cent. It is concluded that careful work by the capillary-tube method which yields values of η essentially higher than this must be interpreted as indicating imperfections in the bore of the capillary. J. W. T. W.

8. *Theory of the Torsion and Rolling Ball Viscosimeters and Their Use in Measuring the Effect of Pressure on Viscosity.* **M. D. Hersey.** (Washington Acad. Sci., J. 6. pp. 525–530, Sept. 19, 1916.)—The torque exerted on the suspended inner cylinder of a torsion viscometer by the uniformly rotating outer cylinder of liquid is found to be—

$$T = \mu n r^3 f\left(\frac{rn^2}{g}, \frac{r^2 n}{\nu}, \text{shape}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where μ denotes viscosity, n revolutions in unit time, r radius of inner cylinder, g gravity, and ν the kinematic viscosity μ/ρ, ρ being the density.

The unknown function f may be determined empirically without altering r. Three interesting cases are: (1) turbulence and drag on bottom negligible, inner cylinder projecting above the free surface; an approximate calculation may be made of the proportions for which the concavity in the free surface due to centrifugal force will serve to secure compensation against speed fluctuations, thus dispensing with a speed governor or stop-watch; (2) torque not independent of the density of the sample owing to spiral flow across the bottom or to turbulent end effects, but free surface level so that the term containing g in (1) drops out; in this case the instrument is self-calibrating, observation with a single liquid of what function of speed the deflection is indicating at once what function it is of the viscosity; (3) a completely immersed cylinder so slender that the end-effects are small and running so slowly that the final deflection is independent of the density; in this case the equations may be integrated and the instrument designed so that it shall have any desired characteristics, reference being made to experiment only after the instrument has been set up and then only to get a more accurate value of the single calibration constant required, namely, T_0, the deflection at unit speed in water. This constant and the free period, t, are the most important constants of performance of such an instrument and are given by—

$$T_0 = 256\pi\frac{\mu_0}{\eta}\cdot\frac{lHr^3}{d_4}\cdot\frac{R^2}{R^2-1}\ldots(2) \quad \text{and} \quad t = \frac{8\sqrt{2\pi}}{d^2}\cdot\sqrt{\frac{Il}{\eta}}\ldots(3),$$

where μ_0 is the viscosity of the standardising liquid, η the shear modulus of the suspension (assumed circular), l the length and d the diam. of the suspension, H the height of the inner cylinder, R the ratio of outer to inner radii and I the moment of inertia of the suspended system; with a large clearance, the instrument is insensitive to changes in outer radius. It is desirable that T_0 be large and imperative that t be small. A simple form of this instrument, in which an ordinary test-tube forms the outer cylinder, has been devised; 30 cm.³ is a sufficiently large sample, and in changing samples one test-tube is bodily removed and the next inserted.

The theory of the rolling ball viscometer is also discussed and its construction for use under pressure. Measurements were made on lard oil and machine oil at different pressures and the value of the pressure coefficient, a, of viscosity $[\mu = \mu_0(1 + ap)]$ at 20° found to be 0·0028 and 0·0032 respectively for the two oils over a range of 200 atmos. It seems desirable to map out the μ, p, t surfaces of all lubricants systematically.

Various equations relating to lubrication might well be generalised to include the effect of pressure, and the author shows how Poiseuille's law may be extended to high pressures. T. H. P.

9. *Principle of Similitude.* **P. W. Bridgman.** (Phys. Rev. 8, pp. 423–431, Oct., 1916.)—In recent papers R. C. Tolman has started a new physical hypothesis and made successful application of it to a number of problems [see Abs. 1488 (1915)]. If this hypothesis should turn out to be correct it would carry with it implications so far-reaching that it might well affect the entire future of physical research. It is, therefore, of the utmost importance to examine the grounds on which the hypothesis rests.

The physical principle underlying it is this. The ultimate elements of which the universe is composed are of such a nature that it would be possible to construct from these elements another universe precisely like the present one, differing only in scale of magnitude. This would mean that other atoms might exist precisely like those of iron, for instance, differing only in absolute magnitude, enjoying great stability like atoms of iron, and giving a series of spectrum lines corresponding one to one with those of iron. There may be a great number of such possible atoms, differing only in scale of magnitude. These twins of the iron atom, being made of the same stuff as the actual universe, are as capable of existence as the actual iron atom in our actual universe. Just this statement of the implications of the hypothesis is not given in the original papers, but it is clearly involved, and the present author learned from correspondence with Tolman that such is his meaning. If the hypothesis is true the finite number of the chemical elements can, therefore, have no explanation in terms of the properties of the protean substance, but must be due to arbitrary selection. This means that every atom of the universe has been individually sorted, or, as J. Herschel put it, bears the impress of a manufactured article. Now such a picture of the universe as this, which places the direct interposition of creative intelligence at a stage nearer to us than the utmost we can hope to reach by experiment, is certainly directly opposed to the entire spirit of physics, and its acceptance is to be forced only by the direst necessity.

Stated in words, as above, the "principle of similitude" is certainly new. But when the hypothesis is formulated into equations, and the equations are applied in solving actual problems, a striking similarity to the familiar methods of dimensional reasoning is apparent. If the exact form of the equations and their mode of application should turn out to be exactly identifiable with the corresponding manipulations of the theory of dimensions, then the principle of similitude must be judged to be not new, in spite of the form of statement above. In the present paper the endeavour is made to show that such an identification is possible; that in so far as the principle of similitude is correct it gives no results not attainable by dimensional reasoning; and that in its universal form as stated above it cannot be correct.

The machinery of the application of the principle of similitude is as follows. For the sake of definiteness, consider the application to that system of measurement which expresses all phenomena in terms of five fundamental units. Let these be mass, m; length, l; time, t; temperature, θ; and electric charge, e. Consider next one of the other possible universes differing in scale from the actual universe by a factor x. In this other universe the unit of length is $l' = xl$, then the principle (as shown in the original papers) gives for the remaining new units, $m' = x^{-1}m$, $t' = xl$, $\theta' = x^{-1}\theta$, $e' = e$. The principle is now applied in any concrete case by demanding that any functional relation correctly connecting the various physical quantities must be such that the same functional relation holds when the accented units replace the original ones. This amounts effectively to demanding that the functional relations shall be such that the factor x cancels out.

This may be illustrated by an example from Tolman. Thus find the form of the relation between energy-density (u) and temperature in a *hohlraum*. It is known experimentally that u is a function of temperature only. The dimensions of u are $ml^{-1}t^{-2}$; hence $u' = x^{-4}u$. Consequently $u = F(\theta)$, and $u' = F(\theta')$, or $x^{-4}u = F(x^{-1}\theta)$. Hence $x^{-4}F(\theta) = F(x^{-1}\theta)$; and $F(\theta) = a\theta^4 = u$, the expression of Stefan's law. In the other universe $u' = a\theta'^4$. It is essential to notice that the constant a has the same numerical value in the two universes.

The ordinary methods of dimensional reasoning may be applied in a form corresponding exactly with the above, with the only difference that when using dimensional reasoning we demand that the functional relations shall be such that they are still satisfied when *each of the five* fundamental units is multiplied by a *different arbitrary* factor. It is not usual to state the theory of dimensions in precisely this form, but that this is equivalent to the usual statement is here shown by the example of the period of a pendulum. Thus if the period be supposed to depend on mass m, length l, and gravity g or lt^{-2}, we have $t = f(lt^{-2}, l, m)$. This relation must still hold when the three fundamental units are changed in any unrelated way. Thus putting $m' = xm$, $t' = yt$, $l' = zl$, we have $yt = f(zly^{-2}t^{-2}, zl, xm)$, but also $yt = yf(lt^{-2}, l, m)$. Hence these two values of yt must hold for all values of x, y, and z. It is readily found that m cannot enter, that g enters as $g^{-1/2}$, and the isolated l as $l^{1/2}$. These give the familiar formula irrespective of the values of x, y, and z which disappear.

It thus appears that the formal machinery of applying the principle of similitude is precisely like that of the theory of dimensions, except that the former is much more restricted. Instead of varying the five fundamental units by *five arbitrary* factors, we are allowed only *one arbitrary* factor, the other factors then being fixed in terms of this one. The principle of similitude would be expected, therefore, to apply to no cases to which the theory of dimensions does not also apply.

After considerable discussion of related matters the question of dimensional theory is again referred to thus :—Suppose the five following quantities are dealt with : the gravitational constant G, the speed of light c, the gas constant k, Planck's h, and the electrical attraction constant E, where force between electrical charge is Ee_1e_2/r^2. Then, if numerical values are denoted by letters enclosed in square brackets, and if these and the fundamental units in two systems are accented and unaccented respectively, we have—

$$\begin{aligned}
G &= [G']m'^{-1}l'^{3}t'^{-2} &&= [G]m^{-1}l^{3}t^{-2},\\
c &= [c']l't'^{-1} &&= [c]\,lt^{-1},\\
k &= [k']m'l'^{2}t'^{-2}\theta'^{-1} &&= [k]\,ml^{2}t^{-2}\theta^{-1},\\
h &= [h']\,m'l'^{2}t'^{-1} &&= [h]\,ml^{2}t^{-1},\\
E &= [E']e'^{-2}m'l'^{3}t'^{-2} &&= [E]e^{-2}ml^{3}t^{-2}.
\end{aligned}$$

These formulæ are usually used to find the numerical magnitudes of the accented numerical factors in terms of the other quantities which are supposed known. But they may be put to another use. If we assign the unaccented units and the numerical magnitudes of the accented and unaccented constants, we may *solve for the accented units.* This is then done. With these equations the magnitude of a new set of units in terms of the ordinary units may be found such that the numerical magnitudes of the five dimensional constants shall be anything we please. Suppose for example a new set of units is sought such that G is the only dimensional constant that changes in value. Then $[h] = [h']$, $[c] = [c']$, $[k] = [k']$, and $[E] = [E']$. Write $[G] \div [G'] = x^2$. Then $l' = xl$, $t' = xt$, $m' = x^{-1}m$, $\theta' = x^{-1}\theta$, and $e' = e$. *These are precisely Tolman's Transformation equations.*

Thus, by purely dimensional reasoning, the author has reproduced Tolman's equations and has shown that they may be correctly applied in all cases in which Tolman has obtained correct results, and he also shows that they may not be applied in the only admitted case in which the principle of similitude fails. It is thus claimed that the principle of similitude contains nothing true which is not already contained in the theory of dimensions.

E. H. B.

10. *Space, Time, and Gravitation.* **W. de Sitter.** (Observatory, No. 505. pp. 412–419, Oct., 1916.)—The author first deals with Einstein's principle of general relativity, but gravitation is not touched upon. He then points out that gravitation differs from all other forces of Nature by its generality and its independence of anything else. The acceleration to which a certain body is subjected at a certain point in the gravitational field does not depend on the chemical constitution nor on the physical status of the body; any other body put at the same place would be subjected to the same acceleration. Let this acceleration a at a certain point be in the direction of the coordinate x_1, thus $d^2x_1/dt^2 = a$. If, now, we perform a transformation of coordinates, introducing a new variable x'_1, and perhaps also a new time t', in such a manner that $d^2x'_1/dt'^2 = 0$, then the acceleration has disappeared. In terms of the new coordinates we would describe the appearances by saying that at the given point there is no gravitation. We can thus produce or abolish a gravitational effect by a simple transformation of coordinates, or, what comes to the same thing, by altering the coefficients g_{ij}. Thus there must be an intimate connection between the values of the coefficients g_{ij} and the gravitational field. These considerations lead to Einstein's theory of gravitation, which can be briefly expressed thus:—In a portion of space where there is no gravitation a material point not subjected to other forces describes a straight line: its world-line is also a (four-dimensional) straight line, *i.e.* a geodetic line in a space in which the g_{ij} have certain constant values. In a portion of space where there is gravitation the world-line of a material point subjected to no other forces is also a geodetic line, but now the g_{ij} have no longer the previous simple values, but are functions of the coordinates. In other words, gravitation is *not* a "force" in the new theory.

From certain considerations of symmetry which leave very little room for arbitrariness, Einstein derives certain equations for gravitation which are invariant. Exactly the same equations have also been derived by Lorentz and Hilbert from a generalised principle of Hamilton, *i.e.* from the condition that a certain function H shall be a minimum. For a given limited portion of the four-dimensional time-space this function H, for the case that there are no other forces, especially no electromagnetic forces, consists of two parts, one of which is the sum of the lengths of all world-lines of material particles within the four-dimensional volume considered, and the other is the mathematical expression for the total curvature of the four-dimensional time-space. Where there is no matter this curvature is zero.

These new equations for gravitation have thus been derived from very general considerations, not based on the old theory of gravitation. These involve no arbitrary constants beyond c and κ, which are nothing more than the ratios of the units of time and mass to the unit of space. In the approximation they lead to Newton's law of gravitation; if the approximation is pushed one order further the well-known anomaly in the motion of the perihelion of Mercury is exactly explained, and no other effects at present within the reach of observation are produced in the motions of the planets or the moon.

If the new theory is accepted gravitation becomes a property of space, in this sense that the same coefficients g_{ij} which determine the metric properties of the four-dimensional time-space also determine the gravitational field. But this same gravitational time-space is the carrier of all other physical phenomena. Thus all physical phenomena must be affected by gravitation. Thus, the world-line of a light vibration is characterised by $ds = 0$. If the g_{ij} are not constant, this is not a straight line, *i.e.* the gravitational field acts as a change in optical density, *i.e.* the rays of light suffer a sort of refraction. A ray of light passing very near the sun, *e.g.* would be bent round it, also the frequency of light vibrations would be affected, so that spectral lines originating in a strong gravitational field—*e.g.* in the sun—would be displaced towards the red.

An important remark must be made as to the coefficients g_{ij} to be determined and the equations to determine them. The coefficients are 10 in number, the independent equations are only 6. They are, therefore, insufficient to determine the coefficients. This is essential. For these coefficients determine the character of the four-dimensional system of reference, and the principle of general relativity requires that this system can be arbitrarily chosen, or else we should again have an absolute space and an absolute time. In order to determine the coefficients we must add four additional conditions, which can be arbitrarily chosen, and which determine the choice of the system of reference. In any system all observable phenomena will be exactly the same. One system may be more convenient than another, but we cannot say that one system is true and another false. **T. J. J. See.** (Ibid. No. 507. pp. 511–512, Dec., 1916.) E. H. B.

11. *Einstein's Theory of Gravitation and its Astronomical Consequences.* I. **W. de Sitter.** (Roy. Astron. Soc., M.N. 76. pp. 699–728, Oct., 1916.)—The subjects dealt with here include those treated in another paper [see preceding Abs.] by the same author, but in the present case the mathematical aspect is much fuller. E. H. B.

12. *The Field of* n *Moving Centres in Einstein's Theory of Gravitation.* **J. Droste.** (K. Akad. Amsterdam, Proc. 19. 2. pp. 447–455, 1916.)—If in one or other field of gravitation there is placed a particle (*i.e.* a body so small that, though influenced by the field, it does not itself exercise any influence on the field) it will move in such a way that the first variation of the time integral of $L=(\sum_{ij} g_{ij}\dot{x}_i\dot{x}_j)^{1/2}$ calculated after some definite way, is zero. Here $x_4=t$, and so $\dot{x}_4=1$. If $\dot{x}_1, \dot{x}_2, \dot{x}_3$ are small with respect to unity (*i.e.* nearly the velocity of light), g_{44} will be much larger than, say, $g_{11}\dot{x}_1^2$. A term is said to be of the first order if, after division by the square of a component of a velocity, it gets a moderate value. Now, as in Newton's theory, which accounts for the phenomena very closely, it follows from the equation of energy that a term, multiplied by the constant of gravity κ, is of the same order as the square of a velocity, and such a term is also called one of the first order, consequently a term containing κ^2 is of the second order. The purpose of the present paper is the calculation of L up to the terms of the second order inclusive. [See also Abs. 686 (1915) and 285 (1916).] H. H. Ho.

13. *On the Perihelion Motion of Mercury and on General Mechanics.* **E. Wiechert.** (Gesell. Wiss. Göttingen, Nachr., Feb.-March, 1916. Phys. Zeits. 17. pp. 442–448, Oct. 1, 1916.)—In his preface, the author deals with Einstein's theory of relativity by which space and time have been deprived of the last traces of objective reality, and contrasts it with Nernst's theory of matter based upon the ether—whose existence is denied by Einstein—as one of the universal fundamentals. Einstein has put forward his theory to give an explanation to gravitation, and the author now brings forward another theory by which the perihelion motion of Mercury is explained, the latter being incapable of solution on the Newtonian hypothesis. In the second

section of the paper some considerations on the inertia of matter are dealt with. The negative result of Michelson's experiment has led to the assumption that material atoms by virtue of their motion experience equal change of form, *i.e.* the Lorentz contraction, and from the behaviour of electrons in magnetic and electric fields a similar contraction is found to take place. The inertia of electrons is also bound up with the contraction. A mathematical exposition of these assumptions then follows, and as the propositions are general for all matter, the perihelion motion of a planet is next studied from this standpoint. Section 3 of the paper deals with the law of attraction on the above basis, while Section 4 dwells upon the significance of the attraction hypothesis. Here the author discusses the explanation of change of mass by assumption of a field energy, and also points out that the electrodynamic behaviour of an electron leads to the view that inertia is bound up with electrodynamic energy. In Section 5 the author summarises his conclusions as follows :—(1) The change of inertia consequent on motion which recent electrodynamics has established, does not suffice to explain the perihelion motion of Mercury. (2) The perihelion motion may, however, be fully explained by the assumption of a gravitational change corresponding to an apparent heavy mass in the gravitation field. (3) These two hypotheses together with certain observation results lead to a value for the perihelion motion. **H. H. Ho.**

14. *On the Special Oscillations of Free Gyratory Molecules.* **F. Krüger.** (Ann. d. Physik, 50. 3. pp. 346–368, June 29, 1916.)—This paper is divided into four sections, the first dealing with the connection between precessional oscillations and specific heat. It is found that the electrons moving in fixed orbits within the molecules, an assumption made in Ampère's electronic theory as also in the theory of spectral series based on Bohr's atomic model, give to the molecules gyratory properties. These gyratory properties of gaseous molecules, and of hydrogen in particular, possess great significance for the kinetic gas-theory. As a direct consequence it is found that the molecules do not rotate, but perform special oscillations of frequency independent of the temperature, or only dependent to a slight extent. This special oscillation is shown to be a precession, and a figure is given to illustrate the gyroscopic character of the hydrogen molecule. By the use of the quanta theory with resonators of constant vibration frequency the temperature variation of the specific heat of hydrogen can be explained in a simple way. Taking the hydrogen molecule based upon Bohr's model, the precessional frequency when calculated is found to be in satisfactory agreement with that estimated from Eucken's measurements of the specific heat of hydrogen at low temperatures. The great difficulties which the application of the quanta theory to rotating molecules encounters are thus removed. In like manner disappear the difficulties which beset the application of classic electrodynamics to the equilibrium between the radiation field and the dipoles rotating within it, a problem dealt with in Section II. The results apply not only to the hydrogen molecule but also to all other gaseous molecules in which revolving electrons are accepted. Section III treats of the precessional oscillations and their connection with the ultra-red portion of the spectrum. For the explanation of the absorption bands in the ultra-red from the standpoint of Bjerrum's theory, the replacement of molecular rotations by precessional oscillations offers advantages. The fact that electrically-neutral elementary gases such as hydrogen, oxygen, chlorine, and bromine, which, according to the measurements of Rubens and v. Wartenberg,

show no absorption bands in the neighbourhood of the ultra-red radiation of 23–314 μ, while gases of pronounced electrical polar character, such as HCl, HBr, H_2O, and in general compound molecules, give strong absorption, is ascribed to the revolution of these electronic doublets: the molecules by virtue of their electrons possess gyratory properties, thereby executing precessional oscillations and not rotational. The ultra-red absorption bands will thus correspond to these oscillations. In general, the position of the absorption bands in the case of oscillations at average temperatures must be essentially independent of temperature, while in the case of rotation the positions of the most likely frequencies are displaced by increasing temperatures towards the shorter wave-lengths. Section IV contains a brief sketch of the importance of precessional oscillations for the theories of para- and dia-magnetism. H. H. Ho.

15. *Rainfall in China.* **C. C. Chu.** (Monthly Weather Rev. 44. pp. 276–281, May, 1916.)—Gives a discussion of the rainfall over China, as derived from observations for the 12 years 1900–1911. There are only 88 stations available, distributed irregularly over the country, at the average rate of 1 station to every 1500 sq. miles; consequently the representation is tentative.

Rainfall in China is dependent mainly upon (1) monsoon conditions, (2) topography, and (3) cyclonic disturbances. The mean annual rainfall varies from less than 50 cm. in the North-west to more than 200 cm. in the South-east, in a strip along the coast in the neighbourhood of Hong Kong. Along the southern coast, and in the region north of the Yellow River 50 % or more of the rain falls in the three summer months, while Central China receives rather less than 40 % during the same period. In the three winter months the percentages vary from 15 in Central China along the coast to less than 2 % in Mukden. R. C.

16. *Atmospheric Transmission.* **C. G. Abbot.** (Science, 44. pp. 495–496, Oct. 6, 1916.)—In continuation of previous correspondence with F. W. Very, concerning the constancy of atmospheric conditions during solar constant observations on Sept. 20 and 21, 1914, it is pointed out that the spectrobolometric results support the view that the transmission was sensibly uniform during that period. Abbot also emphasises the necessity of considering terrestrial radiation emitted at all angles of emergence, and not merely the vertical transmission. C. P. B.

17. *Absorption of Solar Positive Rays in the Earth's Atmosphere.* **R. Swinne.** (Phys. Zeits. 17. pp. 529–532, Nov. 1, 1916.)—Assuming well-known experimental data for the ranges, velocities, and penetrative powers (in gases) of α-particles and H-particles, and applying Bohr's theory of the reduction of velocity of α-particles through gases, the author calculates the velocities of the solar positive rays observed in the Northern Lights. A table is given indicating the hydrogen-equivalent of varying heights of the earth's atmosphere—allowing for the change of composition with increasing height. From these data the author calculates the velocity of α-particles (or H-particles) sufficient to penetrate to various heights (observed frequently in Aurora). Thus at 500 km. V_α is $0{\cdot}78 \times 10^9$ cm./sec., at 140 km. V_α is $2{\cdot}90 \times 10^9$ cm./sec., at 100 km. V_α is $3{\cdot}37 \times 10^9$ cm./sec. Out of 2500 values of parallax determinations 447 give the Northern Lights below 86 km. in height, 22 in the region 86 to 90 km., *2098 from 90 to 129 km.*, 322 from 130–199 km., and 35 from 200 to 350 km. The most penetrating α-particles

yet observed [see Rutherford and Wood, Abs. 689 (1916)] have a velocity $2{\cdot}20 \times 10^9$ cm./sec.—of the same order as the calculated velocities of solar positive rays (8×10^9 cm./sec.—an average value). A. B. W.

18. *Latitude and Time by Simultaneous Transits in the Same Vertical.* **G. T. McCane.** (Observatory, No. 606. pp. 456–462, Nov., 1916.)—Formulæ are developed for reducing observations proposed to be made with a special instrument designed to view simultaneously two stars on the same vertical. The observations should be made as near the prime vertical as possible, and the right ascensions of the selected stars differ by 6 or 18 hours, when required for determination of latitude; when for time the stars should be in or near the meridian. In case both latitude and time are not exactly known, they may be found from two observations separated by a short interval, if made on suitable stars. C. P. B.

19. *Anomalous Dispersion in the Sun.* **C. E. St. John.** (Observatory, No. 506. pp. 462–465, Nov., 1916.)—Julius has stated that an observed mutual influence between neighbouring Fraunhofer lines would support his theory that anomalous dispersion is an important factor in the production of solar phenomena. St. John examines the results obtained from high-dispersion spectra at Mount Wilson, and concludes that the sun-arc displacements for lines with closely adjacent companions do not differ systematically from those for isolated lines; also close pairs show like separations in solar and arc spectra, whether the lines belong to the same or different elements. The observations, as a whole, indicate that, within the limits of error, evidence of mutual action is absent from the solar spectrum. C. P. B.

20. *Radial Motion in Sun-spots.* **J. Evershed.** (Kodaikanal Observat. Bull. No. 51. Nature, 98. p. 196, Nov. 9, 1916. Abstract.)—Improved observations of the phenomena of radial motions in sun-spots have been obtained by the use of instruments requiring less exposure, and by confining the work to the periods of best definition of the spot image. It is shown that the radial motion may be very unequal at equal distances from the umbra. There is usually an acceleration of velocity from the umbra to the outer limits of the penumbra, then a sudden fall to zero or to a lesser speed which diminishes to zero at some distance outside the spot. The radial velocity may amount to as much as 4 km./sec. The diminution of the velocity with increased line intensity, discovered by St. John and ascribed to differences of effective level, is confirmed by the new measures. No difference, however, was found for enhanced lines of iron as compared with arc lines. [See Abs. 18 (1915).] C. P. B.

21. *Ultra-violet Radiation from the Sun.* **K. Birkeland.** (Cairo Sci., J. 8. p. 287, 1916. Nature, 98. p. 177, Nov. 2, 1916. Abstract.)—Regarding the zodiacal light as an indication of the electrical activity of the sun, the ultra-violet radiation was investigated by testing the influence on a photoelectric cell provided with a silver film screen to cut out the visible radiation. Slight variations of intensity were observed, which may be partly ascribed to solar changes. C. P. B.

22. *Orbit of Minor Planet Æthra.* **D. Alter.** (Lick Observatory Bull. [No. 285.] 9. pp. 82–84, 1916.)—Elements are given for the minor planet Æthra, which is strongly suspected of being identical with the asteroid observed at the Lowell Observatory on June 10, 1913. An ephemeris is

given for the period Dec. 1, 1916, to Aug. 1, 1917, in the hope that it may be detected again. The declination varies during this interval from 20° S. to 45° S. C. P. B.

23. *Distribution of Stars in Globular Clusters.* **H. Shapley.** (Observatory, No. 506. pp. 452–456, Nov., 1916.)—As an observer of stellar clusters, the author questions the applicability of the laws of star density derived through comparisons of clusters with gases in adiabatic equilibrium, basing his view on the possibility that the stars counted for the computations may not give even a rough indication of the structure, and also that they may not represent the true distribution of stars brighter than a given magnitude. From the extensive material accumulated at Mount Wilson it is found that (*a*) the extremes of brightness in every system tested differ by not less than 8 and probably by 10 magnitudes; (*b*) several hundreds of the very brightest stars of each cluster are of the redder colour classes, probably corresponding to the giant second-type stars of the galactic system. Negative colour-indices, corresponding to B-type spectra, are not found among the brightest stars, but are frequent among the faintest ones measured. The conditions indicated suggest that physical interpretations of density laws might be possible if the observations could be extended to the average stars. Apart from this, however, in the selection of the brightest stars of the cluster there may be systematic errors in counting dependent on the distance from the crowded centre, or from curvature of field. In addition there is the difficulty caused by the photographic interaction of contiguous images on the plate. The question of the relation of the globular clusters to other features of the universe is considered, leading to the hypothesis that these interesting structures are distinct systems, separate from and virtually independent of the galactic system. Information with regard to their relative size must wait for further work on stellar distances. C. P. B.

24. *Constant of Precession and Systematic Proper Motions of Stars.* **C. de Jong.** (K. Akad. Amsterdam, Proc. 19. pp. 65–97, 1916.)—An investigation is given of the constant of precession and systematic proper motions resulting from a comparison of Küstner's catalogue of 10,663 stars with the zone catalogues of the Astronomische Gesellschaft. C. P. B.

25. *Catalogue of Spectra of* 287 *Faint Stars.* (Hill Observat. Bull. 1. No. 5, [7 pp.], Nov., 1916.)—The catalogue is compiled from photographic spectra obtained at the Hill Observatory, and gives for each star the R.A., Decl., designation, magnitude, spectral type on the Harvard and Kensington systems, and an index letter denoting the relative temperature. C. P. B.

26. *Barnard's Proper-motion Star.* (Observatory, No. 506. pp. 470–471, Nov., 1916.)—An interesting star of the eleventh magnitude, having the largest known proper motion, was discovered at the Yerkes Observatory, in position for 1916, R.A. = 17h. 53m. 44s.; Decl. + 4° 27·4′. Further search has resulted in the star being found on plates taken at the Lick Observatory reaching back to 1894. Pickering has also found records of it on a number of Harvard plates, the earliest of which was taken on 1888 May 22. Further particulars are given in "Astron. Soc. Pacific, Publ., Aug.–Oct., 1916." Aitken gives a proper motion of 9·48″ in position angle 344·3°. Miss Young gives 8·84″ in position angle 354·1°, a month later than Aitken's observation. As seen in the 36-in. refractor at Lick the star is of orange colour and of 10·5

magnitude. Campbell and Moore find its spectrum to be of M *b* type, and the radial velocity —128 per sec. Barnard finds a proper motion of 10·30″ in position angle 359·7°. [See Abs. 44, 1221 (1916).] C. P. B.

27. *Error in Radial Velocity Observations from non-Uniform Slit Illumination.* **W. W. Campbell.** (Lick Observatory Bull. [No. 284.] 9. pp. 30–31, 1916.)—Observations of the planet Venus with the three-prism Mills spectrograph give evidence that an imperfect or unsymmetrical illumination of the slit by the light source may introduce errors in the resulting radial velocities. The results were secured when the terminator of Venus was nearly a straight line, the slit being adjusted parallel to the terminator, and placed just within the illuminated portion, and then just inside the section of the planetary limb opposite the centre of the terminator. A difference amounting to 1·26 km./sec. was found between the differences in two positions of the spectrograph differing by a rotation of 180° about the telescope axis. The difference is ascribed to the variations in guiding owing to the visual image, chiefly in yellow rays, being different in size from the blue-violet image which is registered by the light passing through the spectrograph. C. P. B.

28. *Eclipsing Binary. RX Herculis.* **R. H. Baker** and **E. E. Cummings.** (Laws Obs. Bull. No. 25. Nature, 98. p. 216, Nov. 16, 1916. Abstract.)—A series of observations of photographic magnitudes of this variable have been made by the extra-focal method, and various elements of the system are determined from the results. Estimates of the form and density of each component are included. C. P. B.

29. *Six Stars with Variable Radial Velocity.* **J. H. Moore.** (Lick Observatory Bull. [No. 287.] 9. pp. 37–38, 1916.)—Details are given of six stars found to have variable radial velocity as measured on spectrograms obtained by the Mills Expedition to the Southern Hemisphere, with a two-prism spectrograph. C. P. B.

30. *System of R.S. Sagittarii.* **G. F. Paddock.** (Lick Observatory Bull. [No. 287.] 9. p. 39, 1916.)—Observations were made with a single-prism spectrograph at Santiago, Chile, and preliminary measures on nine plates of the spectrum (Class A) show a range of radial velocity of 160 km., indicating that the star is a spectroscopic binary. It is also known as an Algol variable. C. P. B.

31. *Spectrum of γ Argus.* **G. F. Paddock.** (Lick Observatory Bull. [No. 287.] 9. pp. 40–41, 1916.)—Examination of spectra of γ Argus taken with a three-prism spectrograph shows indications of a break in the principal band designated as λ4652. As the whole band is some 30 Ångström units wide, it is possible that it may be compounded of the two overlapping bands λ4652 and λ4658, which are known to be present in Wolf-Rayet spectra. It is also possible that it may be a reversal of a principal band, as recent results by Worsell at Johannesburg have shown that several bands in the spectrum of this star exhibit distinct reversals. C. P. B.

32. *Wolf-Rayet Bands in Nuclei of Three Nebulæ.* **G. F. Paddock.** (Lick Observatory Bull. [No. 284.] 9. pp. 29–30, 1916.)—Details are given of the spectra of the nuclei of the three planetary nebulæ, N.G.C. 6826, 418, and 40, showing the presence of well-marked bands characteristic of Wolf-Rayet stellar spectra. A line not previously recorded in Wolf-Rayet spectra was observed at λ4657. [See Abs. 289 (1915).] C. P. B.

33. *Modern Positions of Astronomische Gesellschaft Zone Stars.* **R. H. Tucker.** (Lick Observatory Bull. [No. 288.] 9. pp. 17–21, 1916.)—The star places of the A.G. zones are in general use only in cases where a moderate degree of precision is required, owing partly to the uncertainty of proper motions during the 80 years since the epoch of the zone observations. In 1914 some 600 A.G. stars were observed with the Lick Observatory meridian circle, and the results are discussed in comparison with the positions given by the older catalogue, indicating evident systematic differences. C. P. B.

34. *Radial Velocity of β Ursæ Majoris.* **W. W. Campbell and A. M. Hobe.** (Lick Observatory Bull. [No. 284.] 9. pp. 22–26, 1916.)—From measures of plates taken at Potsdam between May 1901 and June 1908, Ludendorff announced a period of 27·16 mean solar days, with a total amplitude 15 km./sec. Observations at Mt. Hamilton at various times from 1901–1914 failed to confirm the variation. In 1915, Guthnick and Prager, observing at Berlin-Babelsburg with a photoelectric photometer, found the star to vary through a total range of 0·02 magnitude, with a period of 0·3122 mean solar day, and linked up the period with Ludendorff's observations. As the quantities involved are so small, three new series of spectrograms were taken at Mt. Hamilton on Feb. 1, 18, and 14, 1916, and have been measured by two observers using different microscopes. The results are not decisive, as the total range is but 48 km./sec., which is about as small as would be expected even on a constant-velocity star with the type of spectrum concerned. No evidence of the changes intensity of the spectrum lines mentioned by Ludendorff were detected on the Mt. Hamilton plates. Details are given of all the plates measured. C. P. B.

35. *Rotation and Radial Velocity of Spiral Nebula N.G.C.* 4594. **F. G. Pease.** (Astron. Soc. Pacific, Publ. 28. No. 165. p. 191, Observatory, No. 506. p. 472, Nov., 1916. Nature, 98. p. 358, Jan. 4, 1917. Abstract.)—From measurements on a spectrogram taken with the 60-in. reflector at Mt. Wilson with 80 hours' exposure, it was found that this nebula had a radial velocity of $+1180 - 2{\cdot}78x$ km./sec., for a point x seconds of arc from the centre. The nebula is seen nearly edge-on to the observer, and the slit of the spectrograph was set along its length so that light was received from points at different distances from the nucleus. The rotational velocity is 330 km./sec. at a distance of 2′ of arc from the centre. C. P. B.

36. *Nebula H II.* 78 *Leonis.* **Mrs. [Isaac] Roberts.** (Roy. Astron. Soc., M.N. 76. pp. 647–655, June, 1916).—This nebula was observed with the Ross reflector at Birr Castle in 1851, 1852, 1868, and first classified as a triple nebula, subsequently recognised as probably spiral. It was photographed by Isaac Roberts at Crowborough on 1902 April 6, with 90 minutes' exposures, showing as a left-handed spiral with bright stellar nucleus and condensations in spirals. Lateral streamers of nebulosity are distinguishable in the northernmost parts of the nebula, passing over nebulous knots. A detailed description is given of all the features visible on the plate, and tables containing the measures of all the objects studied. C. P. B.

37. *Physical Nature of Aurora.* **L. Vegard.** (Ann. d. Physik, 50. 8. pp. 853–900, Sept. 5, 1916.)—Detailed description is given of selected magnetogram traces on nights when observations of auroral activity were secured, and the results are discussed in relation to the theories of electrical discharges from the sun. [See Abs. 868 (1912).] C. P. B.

LIGHT.

38. *Canadian 72-inch Reflector.* **J. S. Plaskett.** (Roy. Astron. Soc. Canada, J. 10. p. 275, 1916. Observatory, No. 506. pp. 471–472, Nov., 1916.)—The new instrument made by Warner and Swasey for the Dominion Observatory at Victoria, B.C., is described with details of the mounting, which is of the English type with the polar axis supported at each end by concrete piers. All the motions of the telescope are to be electrically controlled. The building and dome are being constructed entirely of steel, with double walls and air circulation between. Provision is being made for work at the primary focus 30 ft. from the mirror, and at an equivalent focus of 108 ft. in conjunction with a convex secondary mirror. [See Abs. 679 (1915).]

C. P. B.

39. *Annealing Glass.* **C. V. Boys.** (Nature, 98. pp. 150–151, Oct. 26, 1916.)—In the manufacture of optical glass of many different qualities the question of annealing is one of the first importance, as the glasses differ much in fusibility. Messrs. Adam Hilger, Ltd., have, after a careful investigation, found the means of arriving at the max. temperature necessary, and also the necessary rate of cooling, which may progressively become more rapid. Optical glasses may differ as much as 200 deg. C. in the max. necessary temperature, which may be a long way below any visible softening point. It is desirable not to exceed the necessary temperature, as the very slow cooling at the higher temperature leads to great loss of time. The method adopted by Messrs. Hilger for testing different specimens of glass is interesting as an example of a physical investigation made with a view to practically useful results. Its principle is as follows: A bar of glass, with plane parallel edges, supported as a cantilever, and carrying a load, is set up in an electrically heated muffle, with means for observing the temperature electrically. Polarised light, broken up into interference bands by passage through a Babinet's compensator, is passed through the glass bar, and when the load is applied the bands viewed through the glass appear inclined. If the load is allowed to rest on a support in consequence of slight yielding of the glass, the rate at which the bands change from the inclined to the straight position can be observed for any given temperature. One of the two illustrations accompanying the article shows two specimens of glass undergoing a change of temperature which sets up strains, owing to the difference in temperature between the interior and exterior. The background of the figure is occupied by a system of straight interference bands, which are distorted into curves where they cross the glass bars, owing to the strains. The curvature is much greater for one glass bar than for the other, thus showing that the two specimens are very different. By watching the bands in specimens of glass, Messrs. Hilger are able to ascertain when the glass is hot enough to allow the internal strains to be relieved in a convenient time, and whether, as the glass cools, internal strains are avoided by sufficiently slow cooling. After the stage is reached at which the glass has lost its viscosity, the cooling may be accelerated, and though the bands then become curved, they straighten out again when ultimately the temperature becomes equalised. The loss of viscosity is gradual, not instantaneous, and

there is a progressive permissible increase in the rate of cooling. Messrs. Hilger have thus shown how annealing may be effected perfectly in the minimum of time. Though the research was carried out primarily in relation to optical glass, the apparatus can be applied to chemical glass, or any glass, and Messrs. Hilger, having the apparatus set up in their laboratory, are prepared to test specimens of glass for the trade, and thus provide valuable information as to the best course to adopt in annealing. A. E.

40. *Grinding and Polishing of Optical Surfaces.* **J. W. French.** (Engineering, 102. p. 492, Nov. 17, 1916. Paper read before the Optical Soc., Nov. 9, 1916.)—The original material is referred to as Alpha glass, and the modified material constituting the surface layer as Beta glass. In the case of a metal, the polished surface consists of a layer which covers over small scratches and pits in the underlying material, and when the surface layer is removed by etching these scratches are exposed. When the polished surface of glass is etched, fine scratches appear, and it has been wrongly assumed that glass behaves like metals. Clean scratches comparable to those on metal cannot be formed on the Alpha glass, which splinters in conchoidal fashion. Clean scratches can be formed in the Beta glass layer; they can be filled in by further polishing, and it is these scratches which reappear after etching. The cohesion of the silicates constituting the surface layer on glass is too small to permit of the bridging over of pits, such as minute air bells, that are just exposed, and no evidence of any inclusion of foreign matter in the Beta layer scratches has been obtained. An optical glass surface is produced as follows:—The action of the pitch polisher loosens or liquefies, as it were, the surface layer of molecules, which rearrange themselves uniformly under surface tension. The polishing medium subdivides, breaks up, and removes the surface layer, thus exposing the underlying material. The process then repeats itself, and a perfect surface is obtained only by the removal of material as deep as the bottom of the hollows produced in the glass during the earlier abrasion process. The importance of avoiding the production of deep hollows during the smoothing operation is emphasised. A soft cloth polisher, unlike a hard pitch polisher, sinks into the hollows of the glass and produces an irregular polished surface. The speed of removal of material is slower with cloth. For high class optical surfaces, cloth polishers should not be used at any stage. Surface-layer material, as removed by rouge, on examination was found to consist largely of granules corresponding closely in appearance and size with granules of rouge. The thickness of the surface layer on polished crown glass was measured by heating pieces until the surface layer cracked just as glaze cracks on porcelain. Transverse sections were cut and polished, and the depth of the cracks, that is of the surface layer, was seen to be uniform and about 1/200 mm., or 8 wave-lengths of light. A. E.

41. *Reflecting Power of the Alkali Metals.* **J. B. Nathanson.** (Astrophys. J. 44. pp. 137–168, Oct., 1916.)—The reflecting powers of Na, K, and Rb were determined for various angles of incidence, using white unpolarised light and also monochromatic light polarised parallel and perpendicular to the plane of incidence. A rubidium-argon photoelectric cell was used as a photometer. It was calibrated in terms of known light-intensities by means of crossed nicols. The photoelectric current was found not to be strictly proportional to the light-intensities. The alkali metals were used in the form of mirrors, which were made by distilling or pouring the metal on a

glass plate forming part of an evacuated cell. Reflection at the front and back faces of the glass plate made it necessary to determine the optical properties of the glass plate before the reflecting power of the metal could be found. Incidentally Fresnel's reflection equations for glass were verified. The reflecting power of Na, K and Rb were found to decrease in the order named, *i.e.* as their atomic weights increase. The values for monochromatic light were found to be somewhat higher than those for white light. The results for Rb were found to confirm Maxwell's equation for metallic reflection. In the case of monochromatic polarised light, the reflecting power increased with increased angle of incidence for light polarised parallel to the plane of incidence, but decreased somewhat for light polarised perpendicular to the plane of incidence for the range of angles (8° to 65°) used. The reflecting powers increased with increase of wave-length in accordance with Maxwell's theory. The experiments show that the selective photoelectric effect cannot be due to any marked change in the reflecting powers of the alkali metals for light polarised perpendicular to the plane of incidence, though before the problem can be more definitely decided the investigation will have to be extended to smaller wave-lengths, for the range of wave-lengths employed in the present work covers only about one-half the selective region for potassium and about two-thirds that for rubidium. [See Abs. 747 (1898).] A. W.

42. *Multiple Reflection.* **L. Silberstein.** (Phil. Mag. 32. pp. 487–494, Nov., 1916.)—The purpose of the present paper is to give a simple method of dealing with reflections from any number of plane mirrors. Vector algebra is employed to obtain formulæ defining the ray reflected from any number of mirrors. Various particular cases are considered, special attention being given to the arrangement of mirrors (called central mirrors) which are such that every incident ray is sent back on a parallel path. A. W.

43. *Wave-surface in Iceland Spar.* **A. Guillet.** (Journ. de Physique, 6. pp. 129–142, March–April, 1916.)—Discusses at some length the form of the wave-surface in Iceland spar. The treatment follows Huyghens' classical work, and several interesting results are obtained. The paper contains a number of "illustrative" diagrams and should be consulted by those interested, as a brief abstract cannot be given. A. W.

44. *Echelette Grating.* **A. Trowbridge.** (Phys. Rev. 8. pp. 485–499, Nov., 1916.)—In a previous paper [Abs. 811 (1912)] an account was given of an investigation of the optical properties of a number of gratings the rulings of which were of an approximately triangular form. These gratings were prepared in the manner described by Wood [Abs. 58 (1911)]. The "echelette" gratings studied by Wood, Wood and Trowbridge, and Trowbridge and Crandall were squeezed on gold-plated copper plates which were far from flat surfaces, though for the infra-red energy with which their behaviour was studied they were less imperfect than they appeared to be to the eye. An attempt has now been made to rule on really flat speculum plates gratings which should retain the property of energy concentration exhibited by the rather imperfect echelette gratings hitherto constructed. As it seemed out of the question to squeeze the grooves in so hard a metal as speculum, it was necessary to grind a diamond cutting-tool which would leave the cut with a polish comparable to that of the original surface. The engine with which the gratings were ruled was one constructed in the shop of the Palmer

Physical Laboratory under the direction of Brackett. An account is given here of the features in which it differs from Rowland's engine. The chief difference consists in the use of an advance by worm and gear instead of by ratchet-wheel. The engine in its present state is not capable of ruling high-grade gratings for use in the visible or ultra-violet region, but it is in every way satisfactory for making gratings for use in the infra-red. A number of gratings were ruled, and the results of the tests are given in tabular form, illustrated by graphs. The results show that while the technique of ruling a polished triangular cut in a hard brittle alloy like speculum metal is by no means perfected, at least one of the gratings described (No. 5) satisfies very closely the elementary theory of diffraction from a triangular element even for light of short wave-length, while the observations with the other gratings are in good agreement when energy of longer wave-length is considered. The curves show that grating No. 5 concentrated as much as 90 % of the available energy into the order formed in the position of the oblique image, and that it is particularly suitable for use in the infra-red spectrum in the neighbourhood of $\lambda = 8\mu$, for in this region there is strong concentration into the first order combined with destructive interference in the central image. It should be possible to rule a number of gratings each one of which is as good as that just described in some other wave-length interval. Such a set of gratings would prove a valuable adjunct in the spectroscopy of the infra-red region, for they would combine a high resolving power with an energy concentration comparable with that in a prismatic spectrum. A. W.

45. *Wave Motion of Elementary Vibration Form.* **K. Uller.** (Phys. Zeits. 17. pp. 369–378, Aug. 15, 1916.)—The first part of the paper deals with internal reflection and discontinuities [see Abs. 1102 (1916)]. Experiments to determine wave motion in continuous inhomogeneous bodies have led to the development of the strata method which considers a body as a succession of infinitely thin layers in each of which the wave may be regarded as traversing a homogeneous medium. This presentation, while it affords a means of obtaining the wave-surface, also gives rise to discontinuities due to internal reflection. The problem is therefore raised as to whether these results correspond to reality, since in Nature there are no discontinuities, and the conclusion is drawn that the strata method is inapplicable in the wave theory. Section 2 deals with wave motion in isotropic bodies. The conclusions arrived at are that the theories of Fermat, Malus, and Helmholtz have no general validity; that usually there also exists no Hamiltonian function; and that the radiation is not the sum of the partial radiations of the rectilinear vibrating components into which the elliptical oscillation can be resolved. In the case of slightly curvilinear field lines, the radiations of elastic shear waves are distinguished in shape from those of electromagnetic waves. A brief discussion of refraction concludes the paper. H. H. Ho.

46. *Luminous Efficiency of Incandescent Filaments.* **T. Peczalski.** (Journ. de Physique, 7. pp. 110–124, March–April, 1916.)—The full paper corresponding to Abs. 674 (1916).

47. *Systematic Errors in Measurement of Close Spectrum Lines.* **W. W. Campbell.** (Lick Observatory Bull. [No. 284.] 9. pp. 28–29, 1916.)—Measurements made on a number of the Mills three-prism spectrograms by several observers indicate a tendency to record the separation of close double spectrum lines smaller than the wave-lengths given by Rowland for the same lines in the solar spectrum. Attention is drawn to the necessity of examining very closely any results deduced from measures of such associated lines. C. P. B.

48. *Helium Lines.* **F. Paschen.** (Ann. d. Physik, 50. 8. pp. 901-940, Sept. 5, 1916.)—This paper gives a full discussion of the lines of the helium spectrum, including both spark and continuous-current discharge. The experimental results of Runge and Paschen, Buisson and Fabry, and others, are treated at length with reference to Bohr's theory [Abs. 1042 (1915)]. The Balmer series of hydrogen is also dealt with. A good general agreement is shown between the theoretical and observed wave-lengths, and the values of the universal constants here deduced are also in good agreement with those obtained by other methods. A. W.

49. *Theory of the Stark-effect.* **P. S. Epstein.** (Ann. d. Physik, 50. 5. pp. 489-520, July 25, 1916.)—A mathematical treatment. [See also Abs. 1667 (1915) and 781 (1916).] A. W.

50. *Velocity of Canal Rays.* **T. Retschinsky.** (Ann. d. Physik, 50. 4. pp. 369-384, July 18, 1916.)—A continuation of previous work [Abs. 1407 (1915) and 202 (1916)]. In the present paper a description is given of an investigation of the energy distribution in the electromagnetic spectrum of canal rays, and its dependence on the gas pressure in the observation space, on the gas employed, and the discharge potential. With nitrogen, oxygen, and hydrogen three kinds of ions were observed in the canal-ray beam. The velocities of the faster particles are about 15 % smaller than the values calculated from the discharge potential. The velocities corresponding to max. blackening are shown to be related to those of the energy maxima in the electromagnetic parabolas. Outside the two velocity intervals shown by the atom parabolas, a third maximum is found in the blackening curve, which corresponds to much smaller velocities. In general it can be concluded that it is the particles of one and the same velocity which are deflected by the magnetic and electric field and emit the displaced line in the Doppler-effect. But it is probable that the particles of smaller velocities are relatively more concerned with the light-emission, as is also the case with dispersion. A. W.

51. *The Structure of Spectra similar to that of Hydrogen.* **P. Debye.** (Phys. Zeits. 17. pp. 512-516, Oct. 15, 1916.)—Bohr is credited with the first attempt at making use of the change in electronic mass for the explanation of the structure of the hydrogen lines, although Sommerfeld was the first to put forward a satisfactory and comprehensive theory based on the above standpoint. The quanta assumptions made by Sommerfeld, however, are now found to be not quite as clear as could be desired; the present author attempts to apply a method, evolved by Schwarzschild in his calculation of the Stark-effect to the case of changing electronic mass. This method has the advantage of containing few arbitrary assumptions. In Section I of the paper the differential equation for the chief function is established, while Section II deals with the solution of this Hamilton-Jacobian equation. In Sections III, IV, and V are considered the quanta assumptions, the series formulæ, and their respective development. H. H. Ho.

52. *Zeeman-effect in the Hydrogen Lines, and Stark-effect.* **A. Sommerfeld.** (Phys. Zeits. 17. pp. 491-507, Oct. 15, 1916.)—A paper giving mathematical

theory of the Zeeman-effect, special reference being made to the hydrogen lines in the discussion of the results. The Zeeman-effect is first treated apart from the relativity theory, the two being taken together in the next section of the paper. The quantum relations are then deduced by the method of complex integration. The latter part of the paper deals in a similar manner with the Stark-effect, both with and without the theory of relativity. A. W.

53. *Effect of Electric Field on Spectrum Lines.* **G. Wendt** and **R. A. Wetzel.** (Ann. d. Physik, 50. 4. pp. 419–432, July 13, 1916.)—Describes research on the effect of an electric field on the triplet series of mercury and the doublet series of Al. The method of investigation was on similar lines to that employed by Stark in his work. The results (which are tabulated) show that the lines of the first subordinate, or diffuse, series of the mercury triplets exhibit a greater frequency variation in an electric field than the lines of the second subordinate, or sharp, series. The ratio of the variations is the same as that for the first and second subordinate series of doublets or single lines of He and Li. The electric frequency variation of the first and second subordinate series of mercury triplets increases with increased member-number, and therefore with decreased wave-length, a law which is also followed by all the series lines of H, He, and Li hitherto investigated. Taking the third member of both the first and second subordinate series, it appears that the lines of the first component exhibit a greater frequency variation than those of the third. The Al lines differ in some respects from those of Hg. The latter under the influence of an electric field are narrow and sharp, but the former are generally broader and always diffuse. With the field-strength and dispersion employed a definite separation of the lines of the three first members of the first subordinate series of the Al doublets could not be detected. This was also the case with the second and third members of the second subordinate series. A. W.

54. *The Zeeman-effect and the Quanta Hypothesis.* **P. Debye.** (Phys. Zeits. 17. pp. 507–512, Oct. 15, 1916.)—The work of Einstein, and especially of Schwarzschild [see Abs. 781 (1916)], has demonstrated that by the combination of the quanta hypothesis with Bohr's model, an explanation has been afforded of the Stark-effect. In consequence the state of affairs with respect to the much older Zeeman-effect is very unsatisfactory, inasmuch as there is now no place for the quasi-elastic oscillating electrons which function as energy sources for the series lines in Bohr's equations, although used in all theories for the explanation of the Zeeman-effect from Lorentz to Voigt. In the present paper the author brings forward some considerations with the object of elucidating the Zeeman-effect from the quanta hypothesis. Section 1 deals with the basis of the quanta theory. Section 2 considers the partial differential equation for the chief function of a magnetic field. Section 3 contains the derivation of this chief function. Section 4 treats of the immediate consequences of the quanta theory, and Section 5 the possible frequencies. The author considers his presentation to hold preference over other theories, inasmuch as it brings together in a causal manner both the Zeeman-effect and series formulæ. H. H. Ho.

55. *On the X-rays and the Theory of Radiation.* **C. G. Barkla.** (Roy. Soc., Proc. 92. pp. 501–504, Aug. 1, 1916.)—Experiments on the quality, polarisation, distribution, and the intensity of the scattered radiation from

any given substance show that it is a radiation emitted by electrons, whose motion—that part resulting in radiation—is very completely controlled by the primary radiation. The fact that the simple theory shows that atoms of H, C, N, O, and S contain respectively 1, 6, 7, 8, and 16 electrons with very slight variation, is most remarkable evidence as to the adequacy of an immodified theory of electromagnetic radiation. These results admit of no possible explanation but that every electron in the radiating matter is disturbed by every wave of the primary radiation; that radiation is a continuous process, not depending on any limiting condition; and that it may take place in any quantity. There is not only no suggestion of a quantum or entity of radiation, but the phenomena become absolutely meaningless on any such theory. Recent experiments have shown fairly conclusively that scattering takes place by groups of electrons rather than by individual electrons, when the wave-length is comparable to the size of a group.

The quality of the characteristic X-radiation, the absence of all polarisation effects, the uniform distribution, and the variation of intensity with wave-length of the exciting primary radiation, show that the process of radiation is absolutely uncontrolled by the primary radiation exciting it. The emission of this radiation is conditional upon the primary beam being of shorter wave-length (an extension of Stokes' law). It is not an immediate result of the passage of the primary beam, but arises only indirectly from it, and it takes place only as an accompaniment of an exceptional disturbance of the radiating atom. It is natural to look to the ejection of a high-speed electron as this disturbance. The character of the radiation and the intensity are independent of the speed of ejection or the career of an electron after ejection from the parent substance. The radiation therefore does not originate outside the parent atom, nor does it originate in this electron at all, for this is previously under the influence of the primary radiation. The origin of the radiation must be sought in an atom from which an electron has been expelled.

Careful experiments on the K-absorption, K corpuscular radiation, and K fluorescent X-radiation from bromine lead to the following approximate conclusions:—(1) The energy of primary radiation required to expel a K electron is greater than that per L-electron by the energy of a quantum of K characteristic radiation. The energy of a quantum of K-radiation is therefore the energy required to move an electron from the position and state of a K-electron to the position and state of an L-electron. (2) The energy of primary X-radiation absorbed by each atom from which an electron is expelled varies from just less than two quanta of primary radiation to just more than one quantum, as the wave-length of the primary radiation diminishes. Thus absorption is not in quanta or indivisible units. (3) One quantum of K fluorescent characteristic radiation is emitted for each K-electron ejected. Though there is evidence that with other substances these results do not hold so accurately, the general phenomena and the orders of magnitude are the same. These experimental results suggest that characteristic radiation (say, K-series) is emitted when an outer electron drops into the position of a displaced K-electron, the energy previously absorbed in displacing the K-electron, in excess of that carried away as kinetic energy, being now re-emitted as a quantum of K-radiation, or more probably as a quantum of each of the K, L, M radiations. The various lines in each series may be accounted for.

As the generation of a radiation of given penetrating power or frequency by kathode rays necessitates the incidence of electrons with energy greater than that of a quantum of that radiation even for the production of radiation not recognisable as characteristic of the antikathode, it seems probable that the process of generation of X-rays is one of the same character as that resulting in the emission of characteristic radiation. It is doubtful if mere collisions produce the radiation recognised as X-radiation. There is no conclusive evidence, however, of a limit to the wave-length of the X-radiation which may be generated in any particular antikathode.

Finally, though X-radiation may be and is *emitted* by electrons as a continuous process and in any quantity whatever, it is emitted in quanta from atoms when certain critical conditions are reached. X-radiation is absorbed in very minute quantities—very small in comparison with a quantum—in certain processes. In other processes it is absorbed only in quantities greater than a quantum of the primary radiation—quantities varying from one to two quanta. There is no evidence of absorption of X-radiation in whole quanta.

X-ray phenomena do not support the quantum theory of radiation as generally understood. They indicate that the quantum is a unit of atomic energy rather than of radiation; this unit necessarily appears in certain processes of radiation and absorption. E. A. O.

56. *On the High-frequency Spectra (L-Series) of the Elements Tantalum-Uranium.* **M. Siegbahn** and **E. Friman.** (Phil. Mag. 32. pp. 39–49, July, 1916.)—Complete tables are given of the wave-lengths corresponding to the different lines observed in the L-series spectra of the elements Ta-Ur. At least 11 different line groups have been found for these elements. E. A. O.

57. *On the High-frequency Spectra (L-Series) of the Elements Lutetium-Zinc.* **E. Friman.** (Phil. Mag. 32. pp. 497–499, Nov., 1916.)—With the aid of a vacuum spectrograph [see Abs. 770 (1916) and Phil. Mag. 32. pp. 494–496, Nov. 1916] the high-frequency spectra (L-series) of 32 elements from lutetium to zinc have been examined. For these elements 14 line-groups have been observed. A full table of results is given. [See also preceding Abs.] E. A. O.

58. *Origin of γ-ray Spectra and X-ray Series.* **R. Swinne.** (Phys. Zeits. 17. pp. 481–488, Oct. 15, 1916.)—A discussion of the experimental work on characteristic X-rays and γ-rays, involving the various theories of atom structure and spectral lines. The work of Rutherford, Bohr, van den Broek, Kossel, Sommerfeld, Friman, Debye, Siegbahn, and other physicists interested in this problem is reviewed and criticised in the light of the author's views.

A short comprehensive abstract cannot be given. A. B. W.

RADIO-ACTIVITY.

59. *Magnetic Spectra of the β-rays of Radium D-E, and of Radium and its Products.* **R. F. Kovarik** and **L. W. McKeehan.** (Phys. Rev. 8. pp. 574–578, Nov., 1916.)—The object of this investigation was to map out the β-ray spectrum of RaD and RaE, and of radium and its products. The method adopted involved the actual counting of β-rays by the statistical method. By this means the spectrum obtained for RaD-E agrees with the photographic spectra of O. v. Baeyer, O. Hahn, and L. Meitner [see Abs. 1187 (1911)]. The principal maximum is found to lie near $H_\rho = 2000$ gauss-cm. The spectrum for radium differs from that given by Chadwick [1426 (1914)], who also used the statistical method. The principal maximum lies near $H_\rho = 4000$ gauss-cm. A. B. W.

HEAT.

60. *Interior Temperature of Helical Tungsten Filaments.* **B. E. Shackelford.** (Phys. Rev. 8. pp. 470–478, Nov., 1916. El. World, 68. pp. 1062–1063, Nov. 25, 1916.)—The inside of a helical tungsten filament is noticeably brighter than the outside, and pyrometer measurements of the outside and of the brightest portions of the inside of the same turns of such filaments show the brightness of the latter to be, in some cases, more than twice that of the former. Two possible explanations have been suggested: the interior may be at a temperature sufficiently higher than the exterior, or the increased brightness may be due to the radiation added by reflections within the helix. The examination of the matter is classified under several heads. (1) Angell's formula for the difference in temperature between the inner and outer surfaces of a hollow cylinder (the limiting case of a helix) heated by the passage of a current indicates, for the particular form of helix investigated, a temperature-difference of 0·7 deg. This would give the inside an added brightness of less than 0·5 %, an amount infinitesimal in comparison with the observed effects, which correspond to a temperature-difference of the order of 200 deg. (2) Brightness measurements with a Holborn-Kurlbaum optical pyrometer showed that the outside-inside brightness ratio is greater for a blue than for a red filter, *i.e.* the radiation from the interior of the helix is relatively stronger in the red. If tungsten radiated as a grey body, that is, if the ordinates of the energy distribution curve bore a constant fractional ratio to those of the energy distribution curve for a black body at the same temperature, this result would mean that the inside is actually cooler, for the curve is shifted towards the long wave-lengths. As this is obviously contrary to fact, tungsten must radiate more strongly, proportionally, in the blue than in the red, as has been observed previously, and the radiation from the inside must be "blackened" by repeated reflections. (3) A piece of 0·5-mm. tungsten wire was flattened to about half its original thickness, after which it was polished, coiled with a pitch equal approximately to twice the width of the ribbon, and mounted as a lamp. A photograph of this filament showed a middle dark portion with two adjacent bright portions on either side. In addition to these there may be seen on the rounded edges other light and dark bands. This photograph alone is regarded as almost conclusive evidence that the phenomenon is one of reflection. The central sections of the turns appear dark, since they are viewed normally and there is no opportunity for light to be added by specular reflection. The two central bright bands are seen to be images of the adjacent filaments, which fact accounts for the added brightness. The other bright bands are the images of the next succeeding turns of the helix, and the dark bands correspond to the spaces between the turns. (4) Photographs of the helical filaments were made and cut as templates to transmit only the radiation from the interior and exterior respectively. These were placed in turn against a ground-glass diffusing screen, upon which the image of the helix was then projected. By means of a Lummer-Brodhun photometer, these filaments, operated at 2000° K., were colour-matched against a comparison lamp. When the comparison lamp was adjusted to match the radiation from one of the surfaces, and then that from the other was permitted to

pass into the photometer, the difference in colour was very evident, the interior being redder than the exterior, so that the major portion of the increased brightness must be due to reflected light. (5) Two filaments, one a hairpin the other a helix, were made from the same piece of wire, provided with potential leads approximately one-quarter of the distance away from the ends, and mounted in lamp bulbs. The temperatures of the hairpin filament and of the outside of the helical filament were found to be very uniform over the lengths used. These temperatures were measured with the optical pyrometer, and the resistances were measured by comparing the fall of potential across the lamps with that across a known resistance. It is found that, within the limits of experimental error, the two filaments have the same temperature coefficient of resistance. This would not be the case if the filament heated unduly on the inside, for then the average temperature would be greater than that measured by the pyrometer, the effective resistance would be greater, and the curve for the helix would be steeper. From resistance measurements, therefore, the temperature throughout the helical filament is sensibly that of the outside. J. W. T. W.

61. *Ideal Heat Engines.* **V. Bjerknes.** (Sächs. Gesell. Wiss., Math. Phys. Klasse, 85. No. 1. Phys. Zeits. 17. pp. 335–341, Aug. 1, and pp. 365–369, Aug. 15, 1916. Abstract.)—Contains an account of a type of ideal heat engine which works in a gravitational field. Two straight vertical tubes are connected at both ends by U-tubes, and on them are fixed two heat reservoirs. The working substance circulates through the system as a result of its change of density with temperature ; the flow being adiabatic throughout except when passing the source and sink, whose temperatures and levels are arranged so that the heat exchanges are reversible. The usual expression for the efficiency holds good. Thus with air as working substance if the source is at 0° C. and the sink is 1 m. above, then its temperature must be —0·01° C. and 1/27,300 of the heat absorbed would be converted into kinetic energy. Cases in which the source is below, at same level, and above the sink are discussed at length, and also the case of working substances with abnormal expansion (*e.g.* water). The conclusions reached in the first part of the paper are then applied to the more complicated cases which occur in Nature—resolvable by considering several such simple machines compounded together. It is shown that in a steady, thermally maintained, atmospheric or oceanic stream the sink must necessarily be higher than the source of heat. This important principle was first stated by J. W. Sandstrom in 1916 and applied by him to the discussion of meteorological phenomena. The present paper concludes with a further simple account of its application to atmospheric and oceanic circulation.

D. O. W.

ELECTRICITY AND MAGNETISM.

THEORY, ELECTROSTATICS, AND ATMOSPHERIC ELECTRICITY.

62. *Reciprocity of Electric and Magnetic Phenomena* (I); *Magnetic Currents and Relativity* (II); *Energy Quanta* (III). **D. Berthelot.** (Soc. Int. Élect., Bull. 6. pp. 251–295, June; pp. 333–526, Aug.-Sept.-Oct., and Disc., pp. 545–578, Nov., 1916.)—These papers may be fitly described as a report upon the present state of those branches of physics indicated by the titles of the parts. The treatment is, in the main, descriptive rather than mathematical, and many references to authorities are given. E. H. B.

63. *Possible Influence of a Railway on Thunderstorms in a Hill Country.* **L. Ducasse.** (Electrician, 78. p. 190, Nov. 10, 1916.)—The author has observed that since the construction of a railway from the coast to the central high plateau of Mauritius the distribution of thunderstorms has been altered; and from being equally distributed all over the island they have become concentrated over the higher central regions and have practically ceased on the coastal belt. The suggestion is made by the author and amplified in a note by O. Lodge that in a dry country the surface conduction on the earth may be insufficient to supply the leakage from higher elevations at a sufficient rate to maintain a large potential gradient there. When a railway is laid to the high ground from the coast the rails will act as a conductor and assist in the flow of electricity and so cause an increase in the potential gradient.

J. S. Di.

DISCHARGE AND OSCILLATIONS.

64. *Ionisation by Impact in Mercury-vapour and other Gases.* **F. S. Goucher.** (Phys. Rev. 8. pp. 561–573, Nov., 1916.)—The object of the investigation was to introduce a modification into the method [due to Lenard —see Abs. 1883 (1902)] for the direct measurement of the ionising potentials of different gases, with a view to eliminating certain errors present in all the applications of the method yet made.

As a source of electrons a Pt thimble heated from within by an auxiliary heater was employed, the electron emission thereby taking place from an equipotential surface of comparatively large area, so that lower temperatures can be used than with heated wires. In this way the homogeneity of velocity among the electrons under a given applied field was greatly increased. Employing this method, the following results were obtained:—Hydrogen, 10·25 ± 0·1 volts; nitrogen, 7·4 ± 0·1 volts; mercury-vapour, 4·9 ± 0·1 volts. With the possible exception of hydrogen these are in good agreement with the values given by Franck and Hertz.

By a specially arranged apparatus the form of the current curve for hydrogen was obtained, extending over a range greater than $2V_0$. A similar curve for mercury-vapour, over a range $4V_0$, indicates the probability of a second type of ionisation at approximately 10 volts, and that this value corresponds to that at which McLennan and Henderson have shown the many-lined spectrum to be formed. A. B. W.

65. *Mobility of the Negative Ion.* **S. Ratner.** (Phil. Mag. 32. pp. 441–461, Nov., 1916.)—In the present paper a new method of measuring ionic

mobilities is described. It is based on the production of a wind in an ionised gas when acted on by an electric field, a modification of Chattock's method. Ionic velocities may be measured of the order of from 10 to 10^7 cm./sec.

The apparatus consists of two parallel plate electrodes, one of which contains a gap in which is carried a piece of Pt-foil, flush with the surface. The foil is coated with barium oxide and aluminium phosphate, so that ions of either sign can be produced at will by heating the strip electrically. A circular hole is cut in the second electrode, covered with gauze and placed opposite the Pt strip; behind the gauze is the vane of a specially designed pressure gauge. It is easily shown that if an electric field of intensity x is established between the plates, distance d apart, giving a total ionisation current c, and w is the velocity of the ion in the field x, P the pressure denoted by the gauge of the wind passing through the gauze of the second plate, then $w/x = cd/P$. The ratio w/x is the mobility of the ion. Absolute values of P are not obtained, the mobilities are given relatively to the normal mobility. Various control experiments proving the reliability and efficiency of the method are described.

It is found that at a given pressure the mobility of the negative ion is constant only over a certain range of electric forces applied. With increasing electric force a certain critical value is reached where the mobility begins to increase rapidly. The value of this critical force increases rapidly with the gas pressure: it is equal to 1800 volts/cm. in air at atmospheric pressure. With larger values of the electric force the mobility attains a max. value and then diminishes. It is supposed that the mass associated with a negative ion gradually diminishes with increasing electric force, so that at first the mobility increases with the force; when, finally, the electronic state is reached, the mobility decreases with further increase of the electric intensity. This is predictable from Langevin's formula. Similar experiments were carried out using hydrogen, in which gas the negative ion is known to exist in the electronic state under ordinary conditions. The mobility curves show the same characteristics as in air. The critical value of the electric force is about 40 volts/cm. at atmospheric pressure and at lower gas pressures is too small to be measured. In heavy gases (chloroform, carbon tetrachloride, and methyl iodide) the mobility is constant even with large electric forces and at low pressures. It was found that chloroform vapour, present as an impurity, in amounts as small as 1 part in 10^6, changes completely the aspect of the mobility curves.

According to Wellisch there are two different kinds of negative carriers in a gas, normal ions and free electrons; the proportion of the latter increases with diminution of pressure, but is independent of the electric intensity. To test this theory further experiments are described based on the principle of separating, by means of an alternating field, the normal ions from the free electrons. The results are altogether different from what is to be expected on Wellisch's theory. He assumed that mobility is independent of the electric force, which is only true for comparatively small forces, and there seems little doubt that the sudden increase in the mobility of the ion with increasing force is responsible for the characteristic bends in his curves [see Abs. 1099 (1915)]. For a satisfactory explanation of the results given here a gradual diminution of the average mass associated with the negative ion with increasing electric forces must be assumed.

No abnormality in the mobility of the positive ion could be detected at pressures down to 5 mm. of mercury and with very large electric forces.

T. H.

66. *Application of Electron Theory of Gaseous Dielectrics to Calculation of Minimum Ionising Potentials.* **K. T. Compton.** (Phys. Rev. 8. pp. 412–416, Oct., 1916.)—It is well known that a gaseous molecule cannot be ionised unless the ionising agent possesses an amount of energy which exceeds a critical amount, known as the minimum ionising potential. This potential must refer to the work necessary to extract from the molecule that electron which is least firmly held. This electron is probably the one which may be most easily displaced from its position of equilibrium. In a dielectric, if we consider the contribution of each type of displaced electron to the total electric moment of the medium, it is evident that the most easily displaced electrons will contribute most largely to the total polarisation. We should therefore expect a relation to exist between the minimum ionising potential and the dielectric constant of the gas, and we should further expect that this relation could be definitely determined in case the molecule possesses only one type of electron, or in case the electrons of one type are so much more easily displaced than any others that they may be considered as giving rise to the entire polarisation of the medium. The author shows that

$$\lambda_0 = 6{\cdot}36 \times 10^{-4}[\mathrm{K}-1],$$

where λ_0 cm. is the longest ionising wave-length and K is the dielectric constant. Assuming that hn_0 is the minimum energy required to remove the electron from the atom, which assumption is suggested by Bohr's theory of the atom as well as by Einstein's application of the quantum theory to ionisation by light, he then obtains the relations $e\mathrm{V}_0 = hn_0$,

$$\mathrm{V}_0 = (300h/\pi e)[\pi ne^2/m(\mathrm{K}-1)] = 0{\cdot}194/\sqrt{\mathrm{K}-1}\ ;$$

where V_0 = minimum ionising potential, m = mass of the electron, and n_0 = natural frequency of the electron. None of the quantities λ_0, V_0, or K is known for any gas with very great accuracy. In a few cases λ_0 and V_0 are probably known within 2 or 3 %, and in other cases within 5 or 10 %. Probably the greatest uncertainty is in regard to values of K. In spite of this the author considers that the agreement between the experimental and the calculated values is remarkably good. In the above calculation it is assumed that only one type of electron, the one most easily displaced, contributes appreciably to the value of K. In the cases of Hg, Cd, and Zn the experiments of McLennan and Henderson indicate that there is a second type of electron which requires 3 or 4 times as much energy for extraction as one of the first type. It would be possible to extend the theory to include the effects of more than one type of electrons and to investigate in this way the structure of the atom, but it is doubtful whether the measurements of K and of V_0 can be made sufficiently precise to make such an attempt successful. The success of the present approximate treatment, however, goes to support the recent theories of atomic structure. I. W.

67. *Ionisation Pressure and Corona Current.* **E. H. Warner.** (Phys. Rev. 8. pp. 285–298, Sept., 1916.)—Townsend has shown that the corona can be explained on the basis of ionisation by collision [see Abs. 1595 (1914)]. If the corona is an ionisation phenomena, it is to be expected that at the instant the corona appeared, *i.e.* at the instant the molecules were broken up into ions, the pressure in the apparatus would increase. This pressure-increase was first observed by S. P. Farwell. The above-mentioned theories assume ionisation, but do not account for such a pressure-increase.

Under certain circumstances this pressure-increase can amount to as much as 3 cm. of mercury. It cannot be due to the heating effect of the current, because it occurs very quickly, and if the current is broken in a few seconds the pressure at once returns to its initial value. The heating effect of the current becomes noticeable only after several secs., and then when the current is broken the pressure does not at once return to its initial value but it requires some time for the heated gas to cool. J. Kunz has developed a theory which indicates that $i = v_0(p_1 - p_0)/e +$ a constant, where i is the corona current, v_0 the volume of the gas, e the applied p.d., and $p_1 - p_0$ is the increment of pressure (*i.e.* the ionisation pressure). The author's experiments were carried out with the object of testing experimentally the above equation. The constant potentials were obtained from a battery of d.c. shunt-wound 500-volt generators, connected in series. The experimental tube was of the wire and coaxial cylinder type, the wire used being No. 32 copper. The pressure increase was determined by means of an aneroid gauge, carrying a mirror. When the wire was positive and the case earthed, experiments made with pure dry H, N, CO_2, O, and NH_3 indicated that the ionisation pressure was exactly proportional to the corona current. In the case of oxygen a considerable amount of ozone was formed. The curve as shown is a resultant of two effects: (1) A chemical change due to the formation of ozone; this would tend to cause a decrease in pressure. (2) The increase in pressure due to the ionisation of the oxygen. Since the ionisation curve is a straight line, as is shown by the gases in which probably there is no chemical action, and since this resultant curve of oxygen is a straight line, the following law can be stated:—Whenever chemical action takes place due to the corona the chemical change is exactly proportional to the current. When the wire is negative, beads always appear on it; and since the pressure-increase varies with the arrangement of the beads, which are not stable, it is impossible accurately to verify the above equation. When, instead of the quick-action gauge, an ordinary open manometer, which is slow in its action, was used, it was found that the above equation could be verified very approximately. The increase in pressure in the case of N, showing ionisation, is one of the exceptional cases where N is largely ionised at low temperatures and thus probably chemically active. The apparatus employed could be used as a high-potential voltmeter after calibration. I. W.

68. *Electric Absorption in Discharge Tubes.* **L. Vegard.** (Ann. d. Physik, 50. 7. pp. 769–795, Aug. 17, 1916.)—One of the first systematic researches on electric absorption was due to R. S. Willows. He found that absorption with the same current increases as the pressure decreases, and he came to the conclusion that the absorption could be explained by a chemical combination between the gas and the walls of the tube. E. Riecke found a similar variation with the pressure, but he offered the explanation that the current was carried by two kinds of ions: one, the gas ion, which could show no absorption; the other, ions which are able to be absorbed at the electrodes. During discharge the ratio of these ions present is a function of the pressure, and at lower pressures there are a proportionately larger quantity of absorbable ions present. C. A. Skinner has investigated the problem of the occlusion of gases by the electrodes, and V. L. Christler has continued the work along the same lines. He found that under known conditions the gases investigated were absorbed according to Faraday's law, and, without giving any proof, he asserted that the absorption takes place at the anode.

The author has previously shown that the kathode-fall, and not the pressure, is the important faction in absorption. As a result of the facts then obtained it was thought that a combination of the positive ions in the kathode layer with the metal of the kathode would account for the absorption. It was further pointed out that a number of results obtained by Willows, for which he had given no explanation, could be understood by assuming a connection between kathode-fall and absorption. These results made it necessary for further experiments to be carried out. If the given explanation is the true one, then the absorption mainly occurs at the kathode. On this account it is of special interest to ascertain the part which each electrode plays in the absorption process, and, further, to find out the absorption which takes place with different gases and electrodes under similar conditions. In a previous paper the author had drawn attention to the probability of distinguishing two kinds of absorption which he named "conservative" and "non-conservative."

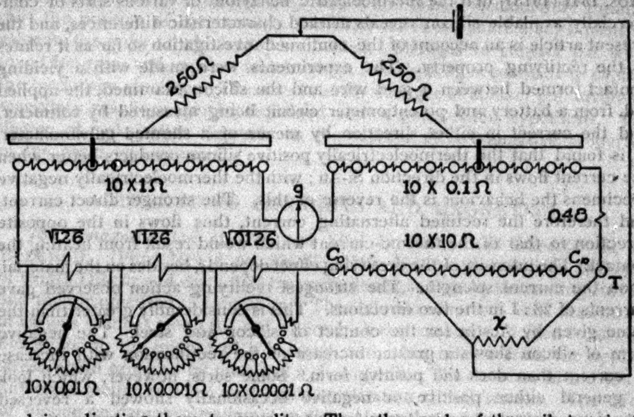
The apparatus now employed is described in detail, and the experimental work is divided into the following sections:—The action of the generation of gas; the absorption in oxygen; the absorption in nitrogen. It is shown that nitrogen behaves similarly to oxygen. The alteration of the absorption is parallel to that of the kathodic tension, but nitrogen shows with normal kathode tension a greater absorption than oxygen The absorption is found to be independent of the anode material and the size of the anode surface, the alteration in absorption only taking place when the metal of the kathode is changed. The absorption in helium and hydrogen are next considered, and then, the connection between absorption and kathode scattering. Finally, the action of a strong magnetic field on absorption and scattering is investigated. These results have enabled two kinds of absorption to be distinguished—one a lasting, proportionately well-defined absorption—"conservative" absorption—and the other a series of distinct absorption processes known to be of different origin—"non-conservative" absorption. The supposition of Willows that the absorption is due to chemical combination between the gas and glass walls must, at least for the conservative kind, be given up, for in the first place no explanation based on this hypothesis is possible for dependence of absorption on the kathode-fall; secondly, the conservative absorption is found to be independent of the nature of the surface of the glass wall, and it was also unaltered by the disturbing action of a strong magnetic field. And finally, there is direct proof that at least part of the absorption is connected with the kathode metal. It appears that up to the present all that is certain is that the conservative electric absorption is connected with the kathode, and is somehow or other caused by collision with the kathode of the quick-moving positive ions (S_1 rays). A. E. G.

69. *Generation of slightly damped, low-frequency Oscillations and Determination of the Circuit Constants.* **H. W. Birnbaum.** (Jahrb. d. Drahtl. Tele. 11. pp. 1–24, Aug., 1916.)—The author describes his arrangements for providing low-frequency oscillations in a condenser circuit by means of suitable interrupters [see Abs. 707 (1916)]. A high degree of constancy is reached with a mercury interrupter. The variations in the oscillations were under 0·5 %. He shows how the constants of the circuit can be determined, without the application of resonance, by the use of a thermo-element and galvanometer· I. W.

ELECTRICAL PROPERTIES AND INSTRUMENTS.

70. *Wheatstone Bridges and some Accessory Apparatus for Resistance Thermometry.* **E. F. Mueller.** (Bureau of Standards, Bull. 13. pp. 547–561, 1916. [Sci. Papers No. 288.].)—Bridges specially adapted for thermometry work are described. Instead of the usual slide wire the smaller steps are obtained by the use of shunts.

The scheme of connections of the bridge is shown in the Fig. The two ratio coils are 250 ohms each and are connected by a short wire which is used in adjusting them to equality. The other ends of the coils terminate in long bars which may be connected by means of plugs to the contact blocks of the 1-ohm and 0·1-ohm decades. The 10-ohm coils are connected to binding-post blocks and the desired number of coils are introduced into the circuit by making connections to the appropriate binding post. If, however, this decade is to be much used it is desirable to employ plug or mercury contacts. Three shunted decades are used to give 0·01, 0·001, and 0·0001 ohm per step respectively. The values of the shunted coils are: $\sqrt{1\cdot26} = (1\cdot1225)$; $\sqrt{0\cdot126}$ $(=0\cdot3550)$; and $\sqrt{0\cdot0126}$ $(=0\cdot1122)$, while the individual values of the shunting coils are given in the table below.



Position of Switch.	0·01-ohm Decade.	0·001-ohm Decade.	0·0001-ohm Decade.
0	11·478	12·245	12·49
1	1·4	1·4	1·4
2	1·75	1·75	etc.
3	2·25	etc.	
4	3·0		
5	4·2		
6	6·3		
7	10·5		
8	21·0		
9	63·0		
10	∞		

It will be observed that with the exception of the first coils the values are the same for the three dials.

The paper gives practical details of accessory apparatus for temperature control of the box, a commutator for use with potential-terminal thermometers, and an interchanger by means of which several thermometers may be successively measured with one bridge. E. G.

71. *The Rectifying Property of Silicon and its Place in the Thermoelectric Series.* **F. Fischer** and **E. Baerwind.** (Phys. Zeits. 17. pp. 373–376, Aug. 15, 1916.)—It has already been shown by the authors and Lepsius [Abs. 1341 (1913)] that the thermoelectric behaviour of various sorts of commercially available silicon reveals marked characteristic differences, and the present article is an account of the continued investigation so far as it relates to the rectifying property. The experiments were made with a yielding contact formed between a gold wire and the silicon examined, the applied p.d. from a battery and potentiometer circuit being measured by voltmeter, and the current in either direction by means of a shunted galvanometer. It is found that the thermoelectrically positive silicon conducts better when the current flows in the direction Si-Au ; with the thermoelectrically negative specimens the behaviour is the reverse of this. The stronger direct current, and therefore the rectified alternating current, thus flows in the opposite direction to that of the thermo-current which would result from heating the contact. The intensity of the rectifying effect depends, besides on the material, upon the current strength. The strongest rectifying action observed gave currents of 28 : 1 in the two directions. This is considerably greater than the value given by Austin for the contact of silicon and steel. The negative form of silicon shows a greater increase of the rectification with increase of current than does the positive form. Some sorts, however, which look in general either positive or negative occasionally showed a reversed behaviour, irregularity also manifesting itself in the rectifying action of these specimens.

It is considered that the rectifying action is not connected in any way with any polarisation due to surface moisture ; and, contrary to Pierce's view, the authors maintain that there is a connection between the thermoelectric power and the rectifying action in the case of silicon. Tissot had already traced such a connection in the case of several substances, but his explanation of the effect would not apply in the case of silicon, owing to the rectified current being opposite in sense to that of the thermoelectrically produced current. L. H. W.

72. *Influences Contributing to the Variation of Contact e.m.f. with Time.* **O. Stuhlmann, Jr.** (Phys. Rev. 8. pp. 294–309, Sept., 1916. Paper read before the Am. Phys. Soc., April, 1916.)—The measurements were made in a copper cylinder, oxidised inside to a matt black. No solder was exposed on the inner side and all grease was carefully removed. This produced a stable and dense surface practically incapable of occluding gases. The metal under examination, in the form of a rod or thin narrow strip, was placed coaxial to the cylinder and insulated from the latter by means of sealing-wax ; the insulated rod was connected to an electrometer. The usual method consisted in noting every 30 secs. the increments in potential of the electrometer, the cylinder being maintained at zero potential and the ionisation being produced by a constant source of γ-rays placed outside the cylinder and on the axis of the latter. As a check a null method was used. For this purpose the cylinder was connected to a potentiometer circuit and the potential adjusted so that no current passed between the cylinder and

the rod. The applied p.d. gave the magnitude of the contact p.d. to 0·002 volt. The author has arrived at the following conclusions:—Variations in contact p.d. of a specific metal are primarily due to the nature and concentration of the occluded gas in the metal. Successive increases in concentration of the occluded gas produce successive decreases in the electro-negative magnitude of the contact p.d., a property common to all gases. All mechanical processes affecting the surface layers of the metal tending to increase the concentration of the occluded gas produce the same change. The gases ozone, oxygen, air, CO_2, nitrogen, hydrogen, and NH_3 if occluded by a metal, shift the position of the metal in the Volta series to a more electro-positive value in the order in which they are named. Changes in contact p.d. were found for gases and vapours which cannot form hydrogen peroxide to explain the secondary reaction. These and similar changes in contact p.d. involving secondary reactions can be explained with a polarisation hypothesis. The degree of polarisation depends on the relative electro-negative properties of the gases and vapours. I. W.

ALTERNATING CURRENTS AND MAGNETISM.

73. *Demagnetisation of Iron and Steel by Strain and Impact.* **G. G. Becknell.** (Phys. Rev. 8. pp. 504–527, Nov., 1916.)—Rods of iron and steel of length 112 cm. and diam. 1·25 cm. were demagnetised by alternating current and then magnetised to saturation. The induction flux was next determined at various sections along the rod, after which the rod was subjected to torsion, flexure, or to the impact of a hammer, and, after release from the applied stress, again explored by means of a sliding coil. The decrease in the flux at any cross-section is taken as the demagnetisation at that section. The effect of torsion on demagnetisation at sections along the rod is such that the ratio, R, of the demagnetisation to the original flux is nearly constant, and is related to the angle of torsion, θ, by the equation $aR = \theta(b - R^2)$, where a and b are constants. Soft Norway iron was found to be far more subject to torsional demagnetisation than Viking steel. The demagnetisation is also related to the distance of the section concerned by an approximately parabolic formula. In the case of flexure of rods of tool-steel, caused by displacing the end of the rod, there is a max. demagnetisation at a distance of a quarter of the length of the rod from the fixed end, *i.e.* midway between the point of max. curvature and the point of max. original flux. The demagnetisation is expressed in this case by the equation $D = k\phi(l - x)$, where k is a constant, l is the length under strain, and ϕ is the flux at distance x. Impact was caused by means of a brass cylinder which could be fastened at any point along a brass rod swung on a horizontal pivot. The energy of the blow could thus be varied and also calculated; the exploring coil in this case remained stationary while the blow was struck. The demagnetising effect of repeating a blow diminishes, but a heavier blow will again increase the effect. It is not possible, however, to render a magnet neutral by means of torsion, flexure, or impact. In the case of impact, the demagnetisation was expressible by the equation $D = c\phi(k - x)$, where c is a constant, and k is a constant greater than the length of the magnet. In general, the demagnetisation caused by impact is due chiefly to vibration of the magnet and also to the wave of compression set up by the hammer at the point of impact. G. E. A.

74. *Method of Generating Alternating Currents.* **B. van der Pol, Jr.** (K. Akad. Amsterdam, Proc. 19. pp. 225–239, 1916 [in English]. Jahrb.

d. Drahtl. Tele. 11. pp. 25–48, Aug., 1916 [in German].)—If a circuit (1) containing resistance and inductance is magnetically coupled with a circuit (2) also containing resistance and inductance and if the current flowing in (1) is suddenly interrupted then the current in (1) will die out asymptotically and a transitory current will be induced in (2) that passes from zero through a maximum and afterwards gradually approaches zero. Mathematical analysis is applied to the case in which *n* similar circuits are coupled to one another in cascade, both for the case in which the last circuit is coupled only to the last but one and also for the case in which the last circuit is coupled back to the first circuit, so as to form a complete chain of intercoupled circuits. The problem consists in the solution of a system of *n* equations of which the following is an example: $i_2r + \mathrm{L}di_2/dt + \mathrm{M}di_3/dt + \mathrm{M}di_1/dt = 0$ with the initial conditions that $i_1 = \mathrm{E}/r$ and $i_2 = i_3 = \ldots = i_n = 0$. The currents in the circuits are found to be expressed as series of exponential terms of rather complicated form, which reduce to simpler form for the case in which the number of coupled circuits is infinite. A numerical case is worked out for 10 circuits coupled so as to form a complete chain. The resistance, self- and mutual induction of each circuit are $r = 4{\cdot}5$ ohms, $\mathrm{L} = 0{\cdot}075$ henry, $\mathrm{M} = 0{\cdot}08$ henry. It is found if the original current i_1 in circuit (1) is taken as the unit, this current falls asymptotically to zero, reaching very small values after 0·15 sec.; the remaining currents are equal in pairs. The currents in the various circuits are calculated and plotted in curves from which the following table of approximate values has been compiled showing the positive and negative maxima passed through by the currents and the times in seconds at which these maxima occur in so far as the max. values are not too small to read from the curves.

$i_2 = i_{10}$	max. time	+ 0·16 0·01		
$i_3 = i_9$	max. time	− 0·05 0.006	+ 0·012 0·05	
$i_4 = i_8$	max. time	+ 0·02 0·004	− 0·007 0·027	+ 0·002 0·10
$i_5 = i_7$	max. time	− 0·009 0·002	+ 0·0048 0·018	− 0·0008 0·045
i_6	max. time	+ 0·0066 0·002	− 0·0085 0·019	+ 0·0011 0·06

It appears that including their initial zero values i_1, i_2, i_3, i_4, i_5, i_6 pass 0, 1, 2, 8, 4, 5 times through zero before approaching zero asymptotically. It is possible by varying the resistances r to make the successive current impulses of longer or shorter duration and the number of alternations produced by an interruption of the primary current can be controlled by a suitable choice of the number of linked circuits. A. J. M.

75. *Equilibrium of the Magnetic Compass in Aeroplanes.* **S. G. Starling.** (Phil. Mag. 32. pp. 461–476, Nov., 1916.)—The deviation of the compass on an aeroplane when under acceleration causes grave errors in estimating the course, and these errors differ considerably from one course to another, being greatest when the aeroplane is in the act of turning. It is taken that as the aeroplane turns, the compass card will remain parallel to the glass, and that the resultant weight of every part is perpendicular to the base-board. The H and V components of the earth's force in the plane of the card are expressed, and the condition of equilibrium is found in terms of the deviation of the compass from magnetic north. This condition is slightly different for the southerly and northerly halves of the complete circle. Taking the dip as 67°, tables are calculated giving the values of the deviation for different angles of tilting and of compass course. The resulting curves show the point towards which the card tends to move; in actual flight, these positions will not be reached. For a tilt, downwards to the south, of 23° (*i.e.* complement of the dip), when the machine is going east there is no controlling field, and the card will set anywhere. For tilts of more than 23°, the compass is reversed when going east, and as the tilt approaches 90° when going north, the compass approximates in action to a dipping needle. For a tilt downwards towards the north, the card comes more nearly into parallelism with the earth's resultant field, and becomes more stable and the deviation diminishes. The method suggested for correcting the chief error depends on the use of a pair of bar magnets placed so as to neutralise the effect of the V component on the needle. If the effect of the H component alone is considered, it is found to be quadrantal (that of the V component being semicircular) and its correction requires the presence of soft-iron bars. G. E. A.

76. *Hall-effect in a Circular Lamina.* **A. Allmenti.** (N. Cimento, 11. pp. 217–220, March–April, 1916.)—Examines the distribution of electric potential (Hall-effect) in a disc of bismuth touched by circuit-wires at certain points. A. D.

RADIOGRAPHY AND ELECTROPHYSIOLOGY.

77. *Radioscopic Measurement of the Depth of Projectiles.* **Charlier.** (Archives d'Él. Médicale, 24. pp. 369–375, Nov., 1916.)—The general principle underlying work of this description is discussed in sections. (1) The geometric principle including (*a*) position of the wounded, (*b*) preliminaries, (*c*) the problem to be solved, (*d*) method of application. (2) Practical details, including (*a*) measurement of the distance "*h*" of the antikathode from the screen, (*b*) measurement of the distance "*d*" between the two successive positions of the bulbs, (*c*) measurement of the distance "*d'*" between the two successive images of the projectile on the screen, (*d*) calculation of "*x*," the distance between the projectile and the screen. A table is appended which gives in mm. the values of "*x*" in function of "*h*," for values of the latter between 500 and 620 mm., and for values of "*d'*" of from 1 to 42 mm., "*d*" being constant and equal to 100 mm. A. E. G.

78. *Principles of Localisation of Projectiles.* **F. de Courmelles.** (Journ. de Physique, 6. pp. 92–103, March–April, 1916.)—A general paper. The double tube is dealt with in some detail, as are also radioscopic methods of localisation which are independent of the distance of the antikathode from the screen. A. E. G.

CHEMICAL PHYSICS AND ELECTRO-CHEMISTRY.

79. *A Critical Test of the Crystallographic Law of Valency Volumes; Crystalline Structure of the Alkali Sulphates.* **A. Ogg** and **F. L. Hopwood.** (Phil. Mag. 32. pp. 518–525, Nov., 1916.)—An account is given of an X-ray investigation into the crystalline structure of the isomorphous alkali sulphates. The dimensions of the crystal units are given in the following table:—

Crystal.	Length of Sides of Unit Rhomb.			
	a	*b*	*c*	Volume of Unit Rhomb.
	cm.	cm.	cm.	cm.3
K_2So_4	$5{\cdot}781 \times 10^{-8}$	$10{\cdot}008 \times 10^{-8}$	$7{\cdot}424 \times 10^{-8}$	$425{\cdot}78 \times 10^{-24}$
$(NH_4)_2So_4$	$5{\cdot}951 \times 10^{-8}$	$10{\cdot}560 \times 10^{-8}$	$7{\cdot}729 \times 10^{-8}$	$485{\cdot}71 \times 10^{-24}$
Rb_2So_4	$5{\cdot}949 \times 10^{-8}$	$10{\cdot}394 \times 10^{-8}$	$7{\cdot}780 \times 10^{-8}$	$481{\cdot}14 \times 10^{-24}$
Cs_2So_4............	$6{\cdot}218 \times 10^{-8}$	$10{\cdot}884 \times 10^{-8}$	$8{\cdot}198 \times 10^{-8}$	$554{\cdot}88 \times 10^{-24}$

The experimental results show that an elementary cell of each crystal in the series contains four molecules, and that the space-lattices of the crystals are strictly comparable with one another. From the above table of results, it is observed that the volumes of the unit rhombs of rubidium sulphate and ammonium sulphate are almost identical, so that the replacement in the elementary cell of eight atoms of potassium by 40 atoms of the eight radical groups NH_4, causes no more distension of structure than if eight atoms of rubidium had replaced the eight atoms of potassium. Further, the substitution of eight atoms of cæsium for eight atoms of potassium causes double the distension of structure that the substitution of 40 atoms of the eight radical groups NH_4 does. This appears to the authors to be conclusive evidence against the general truth of the Law of Valency Volumes due to Pope and Barlow.

Although the complete structure of the series is not solved, the probability of the hexagonal arrangement of the metal and sulphur atoms is pointed out.

E. A. O.

80. *Relation of Molecular Cohesion to Surface Tension and Gravitation: Method of determining a of van der Waals' equation without Assumptions; Meaning of the Constants in the Surface Tension Law of Eötvös, and Latent Heat Formulæ of Dieterici and Mills.* **A. P. Mathews.** (J. Phys. Chem. 20. pp. 554–596, Oct., 1916.)—This paper constitutes a revision and extension of the studies already made on molecular cohesion [Abs. 279 (1914)]. Its contents are briefly as follows: (1) A method of computing *a* of van der Waals' equation from the internal latent heat of vaporisation which seems to be free from all assumptions; (2) a proof that the values of *a* thus found are proportional to the two-thirds power of the product of the molecular weight and the number of the valencies in the molecule; cohesion of a molecule depends, therefore, on the molecular weight and valency; (3) the cohesive attraction of two molecules at unit distance apart is shown to be equal to the two-thirds power of their gravitational attraction at this distance, multiplied

V.
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by the two-thirds power of the ratio of the number of valencies to the molecular weight; or, if M^2K, which is a for a single pair of molecules, is the cohesional attraction at unit distance and m^2k the gravitational attraction of the two molecules at the same distance, then the following relation exists: $M^2K = (m^2k \times \text{valencies/molecular weight})^{2/3}$; (4) a short discussion of the meaning of this relationship between cohesional and gravitational attraction; (5) the theoretical derivation of the relation of cohesion to surface tension and the derivation of Eötvös' surface tension law, $sV_1^{2/3} = C(T_c - T)$, showing what C really is and why it varies from substance to substance; (6) an expression showing the number of layers deep the surface film is; (7) the partial derivation of the relationship $[T_c/(T_c - T)]^{1/3} = d_0/(d_1 - d_v)$; (8) the meaning of the constant C′ in Dieterici's expression of the relationship between the internal latent heat of vaporisation, or $L - E$, and the work done in expanding from the density of the liquid to that of the vapour, or $L - E = C'RT\,ln_e d_1/d_v$; and (9) the meaning of the constant μ' in Mills' expression of the relation of the internal latent heat to the difference between the cube roots of the density of liquid and vapour, or $L - E = \mu'(d_1^{1/3} - d_v^{1/3})$.

T. H. P.

81. *Effect of Oxygen and Silver on the Annealing Properties of Copper.* **G. V. Cæsar** and **G. C. Gerner.** (Am. Soc. Mech. Eng., J. 38. pp. 828–829, Oct., ~~1916~~. Paper read before the Am. Inst. of Metals, Sept., 1916.)—Records the results of a study of half-hour annealing effects, as measured by the scleroscope, produced by the addition of small amounts of oxygen and silver to copper. In the case of pure copper, softening begins at 200° C.; the effect is most rapid between 225° and 275°, and is complete between 300° and 350°. In samples containing oxygen a marked softening effect is associated with the presence of mechanically entangled cuprous oxide. Recrystallisation occurs at a lower temperature, but an increase in oxygen from 0·03 to 0·09 % does not materially effect the softening characteristics. The effect of 0·1 % silver in solid solution in the absence of oxygen is pronounced. The strain-hardened condition persists up to 300° C. and the most rapid softening effects take place in the neighbourhood of 350°. The softening properties of copper containing 0·002 % silver and 0·03 % oxygen approximate very closely to those of pure copper, the two elements having apparently neutralised each other in this respect. C. O. B.

82. *Twinned Crystals in Electrolytic Copper.* **H. S. Rawdon.** (Met. and Chem. Eng. 15. pp. 406–408, Oct. 1, 1916. Paper read before the Am. Inst. of Metals, Sept. 14, 1916.)—The results of observations made on several series of electrotype plates, experimentally prepared for the study of the conditions of deposition which affect their properties, are given. In the microscopic examinations, the frequent occurrence of twinned crystals was noted. The microstructure of the deposits obtained from ordinary acid sulphate baths was as follows:—(1) With low current density the crystals are large and well formed except at the surface of initial deposit. (2) With higher current density the crystals become long and finger-like, giving a columnar appearance to the sections. (3) With still higher current density the structure is considerably broken up and twinned crystals become common.

The explanation given of the origin of these twinned forms is that the rotation of the crystalline units comes as a consequence of the side pressure of neighbouring crystals during the process of growth. The occurrence of the twinned crystals in itself, so far as is known, does not materially affect the mechanical properties of the metal, but the fact that they are brought about by the application of energy is a suggestive index of the mechanical properties. The properties of electro-deposited metals are found to be very similar to those of metals hardened by cold-working. The fact that the deposited metal occurs in a highly stressed condition is clearly pointed out by the effect of annealing, which causes the recrystallisation of the metal, an increase in size of the new crystals, and numerous twinned lamellæ in the new structural forms. C. O. B.

83. *Studies in Measurement of Electrical Conductivity of Solutions at Different Frequencies.* V. *Use of the Vreeland Oscillator and Other Sources of Current for Conductivity Measurements.* VI. *Investigation of Bridge Methods, Capacities, Inductances, Phase Relations, etc.* **W. A. Taylor** and **S. F. Acree.** (Am. Chem. Soc., J. 38. pp. 2396–2403, and pp. 2403–2415, Nov., 1916.)—The Vreeland oscillator is found to be the best and most convenient source of alternating current for conductivity work, because (1) it is practically noiseless and can be started and stopped conveniently; (2) it gives practically a pure sine wave-form; (3) it gives a constant frequency independent of the variation in the actuating direct current; and (4) this frequency can be changed easily to anything desirable for conductivity work. The induction coil should be discarded when measurements of any degree of accuracy are desired. Curtis coils on porcelain spools should be used for all resistances above 10 ohms to prevent errors due to inductance and capacity effects. For greatest accuracy in balancing the bridge a telephone should be used which can be tuned to any desired frequency and which can be attached to a stethoscope. The substitution methods indicated diagamatically above are found to give very good results. R_1 and R_2 are Curtis ratio coils of 100, 500, or 1000 ohms each; C is the cell, T the telephone, S the variable resistance in the bridge, L a variable standard inductance, L_1 a fixed inductance greater than the smallest value of L, K a standard variable condenser, K_1 a variable or fixed condenser with a capacity larger than the lowest value of K if the bridge cannot be balanced by R, and R a set of fine variable Curtis resistances with a range from 10,000 to 0·001 ohm. By simply regu-

FIG. 1

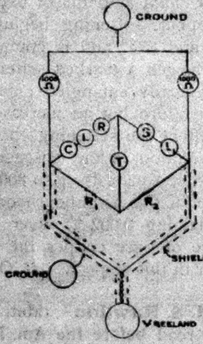
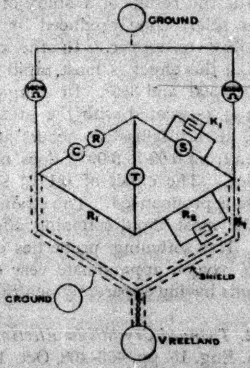


FIG. 2.



lating the temperature of R in Fig. 1, errors due to any changes in the resistance of the bridge coils, or in the inductance, caused by variations in temperature, are prevented, and the experimenter can read the resistances directly without having to make involved calculations. The bath, if made of metal, and also the bridge, should be grounded to prevent errors from capacity effects.

In order to prevent changes in the resistance of the solutions during measurements the cells should be made (1) with any ground-glass joints below the surface of the liquid of the bath, in order to prevent evaporation of the solvent in the cell, (2) with the electrodes well supported by several arms and Pt posts to prevent changes in position of the electrodes, and (3) with the leads to the electrodes sealed off at the end in the glass tubes to allow the experimenter to keep these ends clean and to prevent changes in the resistance of the leads. Diagrams of satisfactory cells are given.

Solutions should be made up and analysed by weight methods in clean resistance glass or quartz containers, and transferred under the water of the bath into clean cells. Resistance measurements on a given solution in a given cell can be duplicated to within 0·001 %, whilst resistance measurements on different parts of the same solution in the same cell, even when no special precautions are taken in filling the cell, agree to 0·01 %. The resistance of aqueous solutions in cells with platinised electrodes did not change appreciably on standing in the cells for 24 hours, whereas cells with bright electrodes showed changes in resistance from 0·05 to 0·14 % in the same time. A comparison of the resistances obtained by the use of (1) an inductance, and (2) a condenser to balance the capacity of the cell showed that the values obtained by the two methods are practically the same, the variation being only ± 0·001 %. T. S. P.

84. *Potential of the Mercury Electrode against Mercurous Ion.* **G. A. Linhart.** (Am. Chem. Soc., J. 38. pp. 2356–2361, Nov., 1916.)—Mercurous nitrate is not a suitable substance for accurate electrochemical measurements, owing to hydrolysis and ready oxidation, so that mercurous perchlorate, which hydrolyses to only a very small extent [Abs. 1578 (1904)], was chosen; moreover, the hydrolytic products are soluble in water. Almost neutral solutions of this salt were prepared by heating pure mercurous oxide with an aqueous solution of pure perchloric acid. The e.m.f.'s of cells made up of a hydrogen electrode and a mercury-mercurous perchlorate electrode were measured, the concentration of the mercurous perchlorate being varied in different cells. The solution of the mercurous perchlorate always contained perchloric acid in excess, so that the degree of dissociation of the former was practically the same in two different cells in which the concentrations of the mercurous chlorate were in the ratio of 1 : 2. The e.m.f. of such concentration cells should be 0·0089 volt, and this was found to be the case in a series of measurements in which the concentration of the mercurous chlorate varied between the limits of 0·0000531 and 0·002750 mol. per litre; the concentration of the perchloric acid varied from 0·0059 to 0·0817 mol. per litre. From these results the potential of the mercurous electrode is calculated to be —0·7928 volt. The results also show that even in the very dilute solutions used there is no appreciable dissociation of $Hg_2^{\cdot\cdot}$ into $Hg^{\cdot}$. T. S. P.

85. *Effect of Pressure upon the Potential of the Hydrogen Electrode.* **N. E. Loomis** and **S. F. Acree.** (Am. Chem. Soc., J. 38. pp. 2391–2396, Nov., 1916.)—The method used in carrying out the experiments described in this paper was to measure the hydrogen electrode in 0·1N-HCl against the calomel electrode in 0·1N-KCl, with no intermediate solution, first at barometric pressure and then at increased or decreased pressure, the temperature being 25°. The apparatus used was similar to that previously described [Abs. 263 (1916)]. The results show that in the neighbourhood of atmospheric pressure the influence of the partial pressure of hydrogen on the potential of the hydrogen electrode can be expressed by the formula $E = (RT/2F)(\log_e H_2/H'_2)$, where H_2 and H'_2 are the partial pressures of the hydrogen, and *n* has the value 1. Five measurements on the system:

$$H_2—Pt—0{\cdot}1\ N.\ HCl—0{\cdot}1\ N.\ KCl—Hg_2Cl_2—Hg,$$

gave the potential 0·42723 ± 3, which is in very close agreement with the average of the author's earlier values, and with those of Bjerrum, namely 0·4272. [See Abs. 416 (1912).] T. S. P.

86. *The Electromotive Forces of Polarisation and the Heats of Formation of Various Salts.* **F. Ollive.** (Journ. de Physique, 6. pp. 124–128, March–April, 1916.)—The anodic (kathodic) electromotive force of polarisation is defined as the minimum e.m.f. necessary to separate the anions (kathions) at the anode (kathode). The minimum e.m.f. necessary to separate the electrolyte into its ions is the sum of these two e.m.f.'s of polarisation. Tables are given of the values of these e.m.f.'s of polarisation for a number of anions and kathions, and from these values the e.m.f.'s necessary to bring about the electrolysis of a number of electrolytes is calculated. These e.m.f.'s are compared with those calculated from thermochemical data and a fairly good agreement is attained. T. S. P.

87. *Separation and Estimation of Nickel.* **T. L. Walker.** (Roy. Soc. Canada, Trans. 9. pp. 93–97, 1915.)—The following method has been investigated for the separation of iron from nickel and cobalt:—The hot solution containing chlorides of Fe, Ni, Co, Cu, and Pb, is oxidised with a few drops of hydrogen peroxide in order to convert all the iron into the ferric condition. After nearly neutralising with sodium carbonate, red lead is added gradually to the boiling solution, until it is seen to be in excess by the distinct red colour of the precipitate. The separation of the iron is complete in a few minutes. After collecting the precipitate, the lead and other metals are precipitated from the filtrate as sulphides, after which the fresh filtrate is concentrated to 100 cm.^{3}, there being then added 8 cm.^{3} of concentrated sulphuric acid and 80 cm.^{3} of strong ammonia; the nickel and cobalt are then deposited on a revolving kathode.

It is found that Ni and Fe can be separated satisfactorily in this way, but not Co and Fe, there being about a 10% loss with Co. Litharge does not give any better result with Co than does red lead. L. H. W.

88. *Electrolysis and Purification of Gallium.* **H. S. Uhler** and **P. E. Browning.** (Am. J. Sci. 42. pp. 389–398, Nov., 1916.)—The pure solution of gallium hydroxide in sodium hydroxide, which was used as electrolyte, was obtained by purely chemical methods from the "leady" residue described in a previous paper [Abs. 782 (1916)]. The conditions for the formation of "trees" by the electrolysis of this solution, as well as the physical and chemical characteristics of the deposit are described. Photographs of the complete arc spectrum of gallium are given, together with a table of wave-lengths, so that the most prominent lines can be identified.

T. S. P.